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AN ANNOTATED LIST OF THE STONEFLIES OF OHIO
(PLECOPTERA)

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While stoneflies constitute one of the smaller orders of insects, they are nevertheless one of the most important groups to both fisheries and sanitary biologists. In mountain streams, they are one of the principal sources of food for trout. Because of their preference for clean, well aerated water, they are becoming increasingly important to sanitary biologists as indicators of clean water conditions in pollutional surveys.

From 1950 to 1953, the author made extensive collections of stoneflies from many of the rivers and smaller streams in southern Ohio. Specimens in the insect museums of the Illinois Natural History Survey, Ohio State University, and Ohio University were also made available for study by the curators of those collections.

The first extensive list of the stonefly fauna of Ohio was published by Walker (1947). In that paper, he reported twenty-four species which he collected during his survey of the stoneflies of southeastern Ohio. In addition, he listed seven other species not taken in that region but reported for elsewhere in the state in publications of Needham and Claassen (1925), Claassen (1931), and Frison (1937, 1942). Seven other species are recorded for the state in publications of Claassen (1939) and Ricker (1952). Eighteen additional species are reported in this paper. Each of these species is indicated by an asterisk preceding the species name. The systematic arrangement followed in this paper is that of Ricker (1950, 1952).

The recorded distribution of each species in the state is given by counties. The names of collectors other than the writer are indicated by initials in parentheses following the county record. Two asterisks following a county name indicates that the writer as well as the collector cited has taken the species in that county. The dates following the lists of counties are the earliest and latest dates of observation or capture of adults of the species in Ohio. Specimens collected by the writer are in his personal collection; all other specimens are in the insect museums previously listed.

The following initials are used for collectors. The abbreviations following each collector's name indicate the location of the collections.

CHK—C. H. Kennedy (OSU)
CRN—C. R. Neiswander (OSU)
DJB—D. J. Borror (OSU)
HHR—Herbert H. Ross (INHS)
HRD—H. R. Dodge (OSU)
HWS—Harold W. Smith (OU)
JDW—John D. Walker (OU, INHS)
JCH—John C. Herron (OU)
JSC—J. S. Caldwell (OSU)
JNK—D. J. and J. N. Knull (OSU, INHS)
JSH—J. S. Hine (OU)
JTL—J. T. Lloyd (CU)
LPR—L. P. Reynolds (OU)
LRE—Lafe R. Edmunds (OSU)
LSR—L. S. Roach (INHS)
PSS—P. S. Shurrager (OU)
RCO—R. C. Osborn (OSU)
RPT—R. P. Thomas (OU)
THF—T. H. Frison (INHS, OSU)
THP—T. H. Parks (OSU)
WER—William E. Ricker (INHS)
WCS—William C. Stehr (OU, INHS)
WPP—W. P. Porter (OU)

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INHS—Illinois Natural History Survey.
OSU —Collection of Department Zoology and Entomology, Ohio State University.
OU —Collection of Department Zoology, Ohio University.
CU —Cornell University Museum.

List of Species

Family **Pteronarcidae**

1. *Pteronarcys dorsata* Say.
Hamilton. December 18, 1952. Naiads only collected.
2. *Pteronarcys pictetii* Hagen.
Reported for Ohio in Needham and Claassen (1925). No county given.

Family **Nemouridae**

Subfamily **Nemourinae**

3. *Nemoura delosa* Ricker.
Clark, Clifton (JNK), Clinton, Delaware (JNK), Greene, Miami, Montgomery. May 7 to July 1.
4. *Nemoura nigritta* Provancher.
Athens. Reported in Ricker (1952). April 25 to May 30.
5. * *Nemoura varshava* Ricker.
Clermont, Clinton, Hamilton. April 25 to May 30.
6. * *Nemoura trispinosa* Claassen.
Greene. June 7 to 11, 1953.
7. *Nemoura truncata* Claassen.
Athens (JDW). April 25, 1941.
8. *Nemoura similis* Hagen.
Athens (WCS, JDW).
9. *Nemoura venosa* Banks.
Athens (WCS, JDW), Delaware (JNK), Franklin (JNK), Greene (JNK), Hocking (JNK, JDW), Tuscarawas (JDW), Vinton (JDW), Washington (WCS). April 25 to June 4.

Subfamily **Leuctrinae**

10. *Leuctra decepta* Claassen.
Hocking** (JDW), Montgomery (LRE). May 23 to June 28.
11. **Leuctra tenuis* Pictet.
Hocking. June 28, 1953.
12. *Leuctra claasseni* Frison.
Athens (WCS, JDW), Greene, Hamilton, Hocking (JDW), Tuscarawas (JDW), Vinton (JDW), Washington (WCS). March 27 to May 22.

Subfamily **Capniinae**

13. *Allocapnia forbesi* Frison.
Athens (WCS), Butler, Clinton, Hamilton, Miami. January 4 to March 11.
14. *Allocapnia granulata* (Claassen).
Athens (WCS), Butler, Clark** (THF), Champaign, Clermont, Franklin (THF), Greene, Hocking (THF), Logan, Miami, Montgomery, Preble (THF). December 9 to March 10.
15. *Allocapnia pygmaea* (Burmeister).
Athens (WCS, THF, JDW), Franklin (RCO), Hocking (THF). February 18 to March 6.
16. **Allocapnia recta* (Claassen).
Clinton, Greene, Hocking (RCO), Logan, Miami, Montgomery. November 6 to March 29.
17. *Allocapnia rickeri* Frison.
Athens (THF), Clermont, Greene, Miami, Muskingum (HHR), Montgomery. January 16 to March 6.
18. **Allocapnia nivicola* Fitch.
Logan. January 19, 1953.
19. *Allocapnia viviparia* (Claassen).
Athens (WCS, THF, JDW), Ashtabula (THF), Butler, Clark** (THF), Clermont, Champaign, Clinton, Fairfield (THF), Franklin ** (HRD, THF), Greene, Hamilton** (THF), Hocking** (THF), Logan, Miami** (THF), Montgomery, Preble (THF), Pickaway (THF), Shelby, Tuscarawas (JDW), Warren. November 2 to May 2.
20. *Allocapnia indianae* Ricker.
Athens (THF), Hocking (THF), Scioto (WER). March 6 to 19.

21. *Allocapnia zola* Ricker.
Hocking (THF, JNK). March 5 to 22.
22. *Capnia opis* Newman.
Franklin (LSR), Hocking (JNK).
23. *Capnia vernalis* (Newport).
Franklin (LSR).

Subfamily **Taeniopteryginae**

24. *Brachyptera fasciata* (Burmeister).
Athens (WCS), Butler, Clark, Clermont, Franklin (RCO), Miami, Montgomery, Shelby, Warren. December 17 to March 16.
25. *Taeniopteryx maura* (Pictet).
Athens (WCS, HWS, JDW), Butler, Champaign, Clark** (THF), Clermont, Clinton, Franklin, (JSH, THF, HRD, LRE), Greene, Hocking (JNK, RCO, THF), Jefferson (THF), Logan** (THF), Hamilton, Miami, Montgomery, Shelby, Warren. November 6 to March 29.

Family **Perlodidae**

Subfamily **Isogeninae**

26. *Isogenus duplicatus* Banks.
Athens (WCS, JDW), Hocking (JNK, JDW), Logan, Tuscarawas (JDW), Vinton (JDW). March 16 to May 22.

Subfamily **Isoperlinae**

27. *Isoperla bilineata* (Say).
Athens (WCS, JDW), Butler, Franklin (RCO, 1899), Hamilton, Hocking** (WCS, JDW), Licking (CRN), Miami, Montgomery, Tuscarawas (JDW). April 27 to July 11.
28. **Isoperla burksi* Frison.
Butler. April 28, 1953.
29. *Isoperla confusa* Frison.
Athens (WCS, JDW), Clermont, Clinton, Hamilton, Miami, Shelby, Tuscarawas (JDW). January 9 to April 25. Adults taken only on April 25.
30. **Isoperla decepta* Frison.
Butler, Clermont, Clinton, Hamilton, Greene, Logan, Warren. April 7 to May 30.
31. *Isoperla minuta* (Banks).
Champaign, Clark, Clinton, Darke, Franklin (RCO, JNK), Greene, Licking (RCO), Logan, Miami, Preble. April 10 to June 16.
32. **Isoperla orata* Frison.
Hocking, Logan. May 30 to June 28.
33. **Isoperla transmarina* (Newman).
Logan. May 19 to 22.
34. **Isoperla clio* Newman.
Greene (CHK). 1934.

Family **Chloroperlidae**

Subfamily **Chloroperlinae**

35. *Alloperla imbecilla* (Say).
Hamilton. Recorded from Cincinnati by Claassen (1939). No date given. Hocking (RCO). May 28, 1936.
36. **Alloperla idei* Ricker.
Hocking. May 23, 1953.
37. **Alloperla caudata* Frison.
Hocking. June 28, 1953.
38. *Alloperla mediana* Banks.
Logan. May 12, 1953.
39. *Hastaperla brevis* (Banks).
Athens (JDW), Hocking** (JNK, WCS), Logan. May 12 to 30.

Family **Perlidae**

Subfamily **Perlinae**

40. *Neoperla clymene* (Newman)
Athens (WCS), Adams (CRN), Butler, Clermont, Clinton, Franklin (CHK), Miami, Montgomery, Ottawa (CHK), Ross (CHK), Warren. May 2 to August 15.

41. *Neophasganophora capitata* (Pictet).
Athens (JDW), Butler, Clark, Clermont, Clinton, Delaware (JNK), Franklin (CHK), Greene, Miami, Montgomery, Pickaway (JSC), Preble, Shelby, Warren. May 2 to July 23.
42. **Paragnetina media* (Walker).
Champaign, Miami. May 13 to June 4.
43. **Perlinella drymo* (Newman).
Butler. March 10, 1953.
44. **Atoperla ephyre* (Newman).
Butler, Licking (RCO). May 27 to June 7.
45. *Perlesta placida* (Hagen).
Adams (CHK), Athens (WCS, RPT), Butler, Champaign, Clermont, Clinton, Clark, Delaware (JNK), Franklin (JNK, DJB), Greene** (JNK), Hamilton, Hocking** (JNK), Holmes (RPT), Knox (DJB), Logan, Lucas (WCS), Medina (JNK), Miami, Montgomery, Preble, Ross (CHK), Scioto (CHK), Shelby, Warren. March 21 to July 19.
46. **Perlesta cinctipes* Banks.
Butler, Clinton, Darke, Greene, Hamilton, Miami, Preble, Shelby. May 20 to June 17.

Subfamily **Acroneurinae**

47. *Acroneuria arida* (Hagen).
Athens (WCS), Adams (CHK), Franklin (CHK), Greene (JNK), Holmes (RPT), Hocking (JDW), Ross (CHK), Ottawa (PSS, RCO, CHK). May 30 to July 7.
48. *Acroneuria abnormis* (Newman).
Athens (WCS, JDW), Butler (RCO), Lawrence (RCO), Ross (CHK), Miami, Warren, Washington (LPR). May 30 to July 16.
49. *Acroneuria evoluta* Klapalek.
Adams (CRN), Athens (JCH), Butler, Clark, Clermont, Clinton, Delaware (JNK), Darke, Greene, Hamilton, Hocking, Logan, Miami, Montgomery, Preble, Ottawa (RCO), Shelby, Warren. May 20 to August 30.
50. *Acroneuria filicis* Frison.
Athens (WCS, JDW). April 25 to July 11.
51. **Acroneuria internata* (Walker).
Clermont, Franklin (RCO). March 1, 1952 and 1934 (RCO). Naiads only collected.
52. *Acroneuria lycorias* (Newman).
Recorded from Ohio specimens in the Illinois Natural History Survey Collection by Frison.
53. *Acroneuria mela* Frison.
Adams (JSH), Athens (JCH), Warren. June 26 to 28.
54. *Acroneuria perplexa* (Frison).
Athens (WCS, JDW), Hocking** (JDW). June 15 to July 23.
55. **Acroneuria ruralis* (Hagen).
Franklin (RCO), Hamilton (JTL). June 1 to July 12.
56. *Acroneuria xanthenes* (Newman).
Athens (WCS, JDW), Hocking. May 2, 1953.

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TWO PLEISTOCENE MOLLUSCAN FAUNULES FROM HUNTER'S RUN, FAIRFIELD COUNTY, OHIO

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INTRODUCTION

The two molluscan faunules described in this paper were collected during a routine examination of the glacial deposits of Fairfield County, Ohio. The Mollusca were identified by one of us (La Rocque); the description of the field data by the other (Conley).

The collections are of particular interest because they accompanied material that could be dated by the radiocarbon method (results not yet available) and are of the same geologic age as deposits containing material already dated (see below) by the same method. In addition, the species represented are recorded for the first time in late Tazewell? (Bloomington) deposits in central Ohio and their presence there may throw some light on the Pleistocene migration routes of two interesting species, *Hendersonia occulta* (Say) and *Deroceras* cf. *D. aenigma* Leonard.

GEOLOGIC SITUATION

The specimens collected came from an artificial cut along the southern bank of Hunter's Run, in the southwestern quarter, section 10, Hocking Township, Fairfield County, two and one-half miles southwest of the town of Lancaster. The stratigraphic section is shown graphically in figure 1 and may be described as follows:

Unit	*Description*	*Thickness (feet)*
4	Sand, brown, bedded, oxidized and leached, fossiliferous	3.5
3	Sand, gray, bedded, calcareous, unfossiliferous	4.0
2	Gravel, gray-brown, bedded, calcareous, unfossiliferous	1.0
1	Loam, silty, gray, organic, poorly calcareous, fossiliferous	4.5
	Base of section not exposed.	

Unit 1, in addition to Mollusca, contained preserved fragments of moss, grass seeds, and tree roots. It resembles muck soils found in marshy areas along creek banks. Mechanical analysis of the material from this unit showed that it contained 19.6 percent sand, 59.8 percent silt, and 20.6 percent clay.

Units 2, 3, and 4 appear to be river alluvium. Unit 4 contained partially decayed tree roots and nuts of the buckeye and walnut trees, as well as Mollusca.

The locality described is south of the Johnstown-Marcy moraine which can be traced across the central part of Fairfield County. The Wisconsin terminal moraine lies across the southern part of the county. Study of soil profiles and depths of leaching indicate that this terminal moraine contains drift of two ages. The deposits discussed in this paper lie in the area of the younger drift of the terminal moraine.

POSSIBLE AGE OF THE DEPOSITS

A piece of wood (sample W-88) found in till outside the Johnstown-Marcy moraine at Newark, Licking County, Ohio was dated by the radiocarbon method

at 21,400 ± 600 years (Goldthwait, 1955, p. 58). Another, earlier and less reliable determination (sample C-893) of the same material gave an age of 16,100 ± 850 years. This suggests that the Johnstown-Marcy moraine is of very late Tazewell (Bloomington) age and that the younger tills of the Wisconsin terminal moraine are probably of middle Tazewell (Bloomington) age. Although wood samples taken from the lower gray bog deposit (unit 1) of our section have not yet been dated by radiocarbon, a general date can be inferred for the deposit. Since it is found in the area of the younger (middle Tazewell?) drift of the Wisconsin terminal moraine, the bog must have formed after the retreat of the early and middle Tazewell? ice. The bog probably existed until drainage was again established in the area by Hunter's Run and the deposition of the sands and gravel of the stream above the bog deposit.

TABLE 1

Composition of Hunter's Run Molluscan Faunules

Unit 1 Species	No.	Unit 4 Species	No.
Deroceras cf. *D. aenigma* Leonard	28*	*Sphaerium simile* (Say)	11
Retinella sp. (fragments)	3	*Sphaerium* sp., undetermined, but not *S. simile* (Say)	4
Oxyloma cf. *O. retusa* (Lea)	13	*Goniobasis livescens* (Menke)	13
Hendersonia occulta (Say)	2	*Physa* sp., fragment	1

*In both collections, specimens are too few to justify reduction to percentages.

COMPOSITION OF THE MOLLUSCAN FAUNULES

These two collections, separated by only a few feet of sediments, are totally unlike in composition. The lists of species are given in table 1. It is apparent that the assemblage from unit 1 is terrestrial and that from unit 4 is fresh-water.

INTERPRETATION OF THE MOLLUSCAN FAUNULES

The molluscan assemblage in unit 1 is one that could be expected along the wet margins of creeks and rivers, in a moist environment, usually under heavy vegetation, probably also with a sparse tree cover. From a climatic standpoint, this appears to be a "cold" fauna rather than a "warm" one but the list is too short to provide firm conclusions. The presence in this assemblage of *Deroceras* cf. *D. aenigma* Leonard and of *Hendersonia occulta* (Say) is noteworthy.

Deroceras aenigma Leonard (1950, p. 38) occurs in the Pleistocene of Iowa, Nebraska, Kansas, Oklahoma, and Texas. The type locality is Aftonian according to Leonard (1950, p. 38), Upper Pliocene according to Hibbard (1956, p. 149). The specimens are the internal shells of land slugs (Mollusca: Gastropoda) and they have been separated specifically from the living species of the genus *Deroceras* because of the constantly greater size and thickness of the shell. The Ohio specimens are also thicker than shells of living *Deroceras* but are not as large as those of the mid-continent species. If our specimens are indeed *D. aenigma* Leonard, they represent a new record for the distribution of the species and the first record for the Pleistocene of Ohio. The species is absent from the faunules described by Leonard (1953, p. 372) from the Pleistocene (Sangamon, Farmdale?, and pro-Tazewell) of the Cleveland region.

Hendersonia occulta (Say) has been recorded doubtfully as living in Ohio (Sterki, 1907, p. 384) but van der Schalie (1939, p. 4) does not accept the record,

and rightly, since it has never been substantiated by further collecting. Leonard (1953, p. 372) found *H. occulta* in all four samples from the Cleveland area and notes (1953, p. 374) that it is abundant in the Cleveland loess (pro-Tazewell). The Hunter's Run record is, therefore, the second for Ohio and probably the second also for deposits of Tazewell age in the state. Its presence in other Pleistocene deposits in Ohio may be expected.

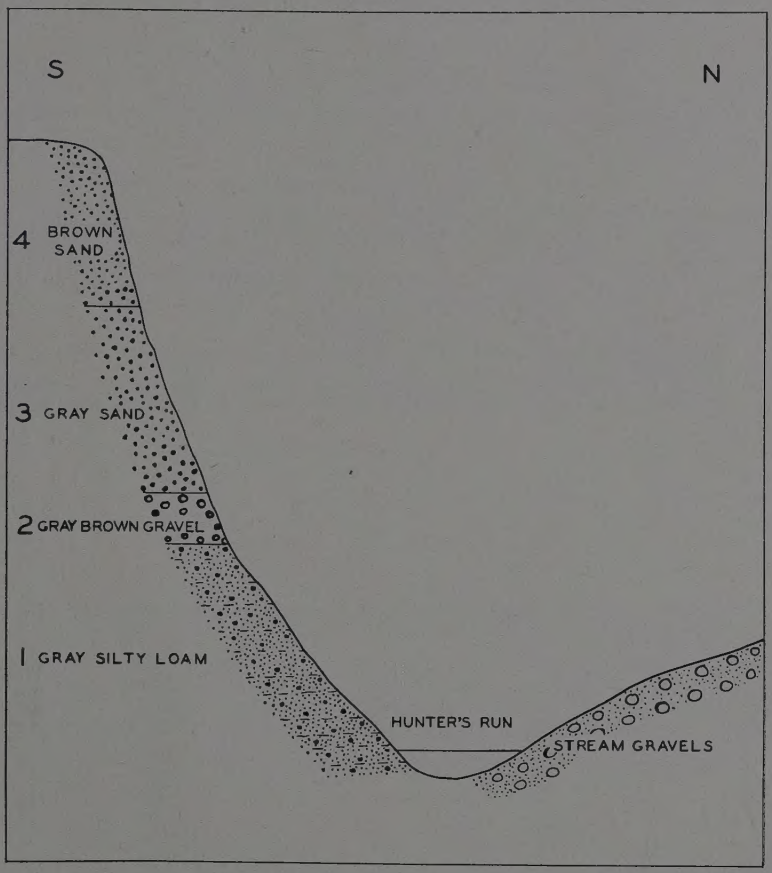

FIGURE 1. Diagrammatic section of the Hunter's Run section. Numbers correspond to the units of the measured section in the text.

The molluscan assemblage of unit 4 is of an entirely different nature. Such an assemblage could be found in creeks and small rivers of Ohio, at least in those whose molluscan fauna has not been wiped out by pollution. The absence of Naiades (freshwater mussels) is noteworthy but not surprising.

Both the nature of the sediments and the molluscan fauna point to the same conclusions concerning environment. At the time when unit 1 was being deposited, the site was probably a moist floodplain, in the vicinity of a stream. Influx of

alluvium with the deposition of units 2 and 3 indicates change in environment, probably connected with glacial events, and either a shifting of the stream existing during the deposition of unit 1 or the development of a new, larger stream. The stream remained devoid of molluscan population for a time, represented by the deposition of units 2 and 3, then was invaded, probably from the south, by a typical small-stream assemblage of Mollusca. The stream in question may have been the present-day Hunter's Run. In any event, this stream has cut down into the Pleistocene deposits to the level of the oldest deposit in the exposed section.

ACKNOWLEDGEMENT

We gratefully acknowledge comments and criticisms by R. P. Goldthwait relating specially to the age of the deposit.

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The Natural Landscape and Natural History of the Athens State Hospital Grounds. *Frank M. Semans.* Issued by the Athens State Hospital, Athens, Ohio. 1955. 24 pp. mimeographed. Free Distribution.

The Athens State Hospital grounds have a reputation for natural beauty. The author of this bulletin has brought together material on the natural history of the area. Included are a report on the stratigraphic records of a rock cut, by Myron T. Sturgeon; a list of the woody plants, by William G. Gambill, Jr.; and a list of the vertebrates observed on the grounds, by Henri C. Seibert.

The bulletin will provide useful information for those interested in the natural history of Ohio.

EDWARD S. THOMAS

Microwave Spectroscopy. *C. H. Townes* and *A. L. Schawlow.* McGraw-Hill Book Company, Inc., New York. 1955. xviii+698 pp. $12.50.

This volume is concerned primarily with the Microwave Spectroscopy of gases. The basic theory of atomic and molecular spectra is presented critically, systematically, and in the simplest way consistent with completeness. The material may be profitably read by anyone with an elementary knowledge of quantum mechanics and atomic physics. A rather complete account of the microwave techniques which are especially useful in microwave spectroscopy is included. Appendices give most of the tables and information needed in doing research.

This book should prove to be of major importance to students and research workers interested in microwave spectroscopy. It will serve as an excellent guide to anyone interested in doing research in this field, as well as an excellent text for anyone wishing to broaden his knowledge with respect to this important and relatively new field of physics.

FRED P. DICKEY.

A STUDY OF THE LIFE HISTORY OF THE FORKED FUNGUS BEETLE, *BOLITOTHERUS CORNUTUS* (PANZER)

(COLEOPTERA: TENEBRIONIDAE)[1]

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The forked fungus beetle, *Bolitotherus cornutus* (Panzer), is a common inhabitant of polyporoid fungi in forested areas, especially beech-maple, east of the Mississippi River. Although descriptions and brief life history notes concerning *B. cornutus* (also known as *B. bifurcus*) have appeared in the literature, no extended study of its development and habits has been published.

This study was made by rearing the beetle in the laboratory and observing it in the field. Although some observations were made in Hocking County, Ohio, from February through May, 1954, the majority of the laboratory and field work was conducted in the vicinity of the University of Michigan Biological Station, Cheboygan County, Michigan, during the summers of 1953 and 1954. Overwintering material was obtained from that area.

METHODS

Food for laboratory cultures of larvae was prepared by grinding dried, apparently uninfested conks of *Fomes applanatus* (Pers.) Gill. to the consistency of fine sawdust with a micro-pulverizer. This material was autoclaved to reduce mold, and stored in plastic bags.

For larval development studies, a one-third inch layer of the ground fungus was placed on several layers of wet paper toweling in a stentor dish, and covered with a single layer of damp toweling. One freshly laid egg, removed from the host fungus, was placed on this toweling and the larva, on hatching, burrowed through it into the fungus material. The labeled and covered stentor dishes were kept on a darkened shelf. The fungus material in these dishes was changed daily and the removed material was inspected for cast larval skins.

Adults collected in copulation were isolated in pairs and daily records were kept of the oviposition of the female of each pair. The mated pairs were isolated in fingerbowls containing wet paper toweling and a small specimen of *F. applanatus* showing no previous oviposition. These fungi were freshly collected from a beech-maple area, William's Corners, Cheboygan Co., Michigan. The bowls were labeled, stacked together, and placed on a darkened shelf in the laboratory.

In a beech-maple area, regular collections of infested fungi were made from stumps of trees cut five or six years prior to the collecting season. Some of these specimens were broken apart and examined; others were kept in screen cages for observation purposes.

Daily observations were made on the laboratory material, especially between 4:00 P.M. and 10:00 P.M. Two or three times a week, the nocturnal activities of the beetle were observed in both laboratory and field between 11:00 P.M. and 4:00 A.M.

DESCRIPTION OF STAGES

The eggs of the forked fungus beetle were first described by Weiss and West (1920) as follows:

[1]From a thesis presented in partial fulfillment of the requirements for the degree Master of Science, The Ohio State University, 1955.

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"The blisters or egg capsules were composed of dark excrement-like material, each being oval or sub-oval in outline, about 3.5 mm. long, 2.5 mm. wide, and from 1 to 1.5 mm. high in the center, sloping toward the edges. The average thickness of the wall of a capsule was about 0.5 mm. . . . The translucent eggs were cylindrical with broadly rounded ends and varied in length from 1.7 mm. to 2 mm., and in width from 0.8 mm. to 1 mm. The outer covering of each egg was whitish and marked with slightly raised dots."

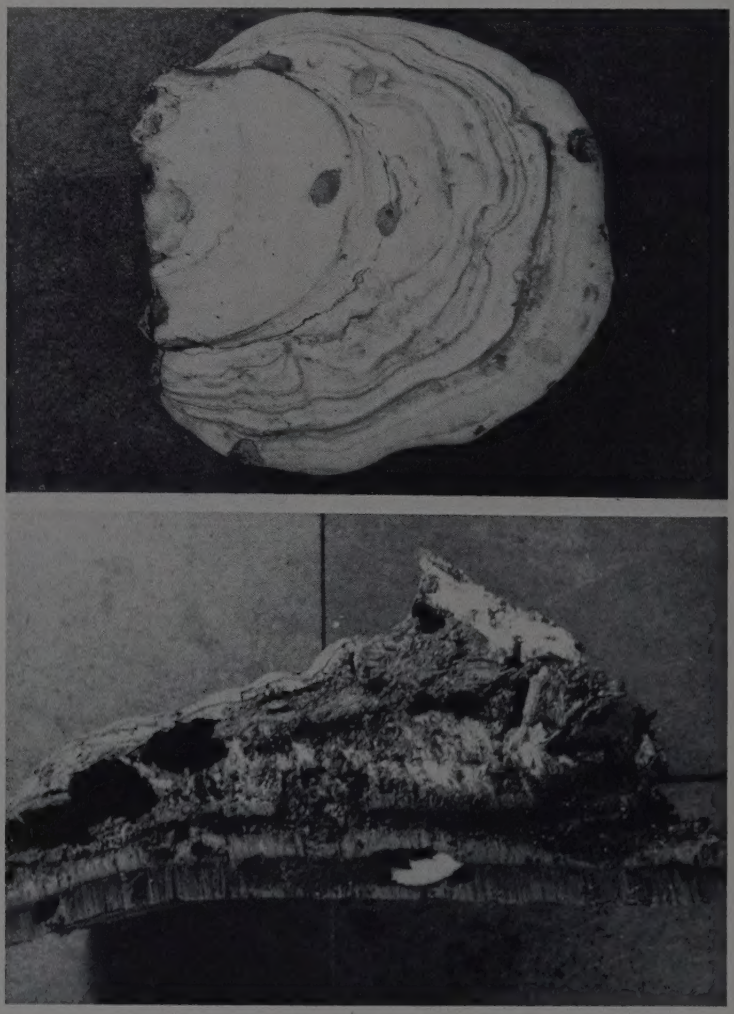

FIGURE 1. (above) A specimen of *Fomes applanatus* showing egg capsules of *Bolitotherus cornutus* (Panzer). A larval emergence hole is visible in the capsule in the center of the picture.

FIGURE 2. (below) Cross section through *F. applanatus*, showing chambers and tunnels occupied by *B. cornutus*.

Eggs collected in the Michigan area were as described by Weiss and West, but the average size of the capsule covering the egg varied from that of the original description. Egg capsules on the upper surface of the fungus were generally longer and wider (averaged 3.8 mm. in length, 2.7 mm. in width, and 1.5 mm. in

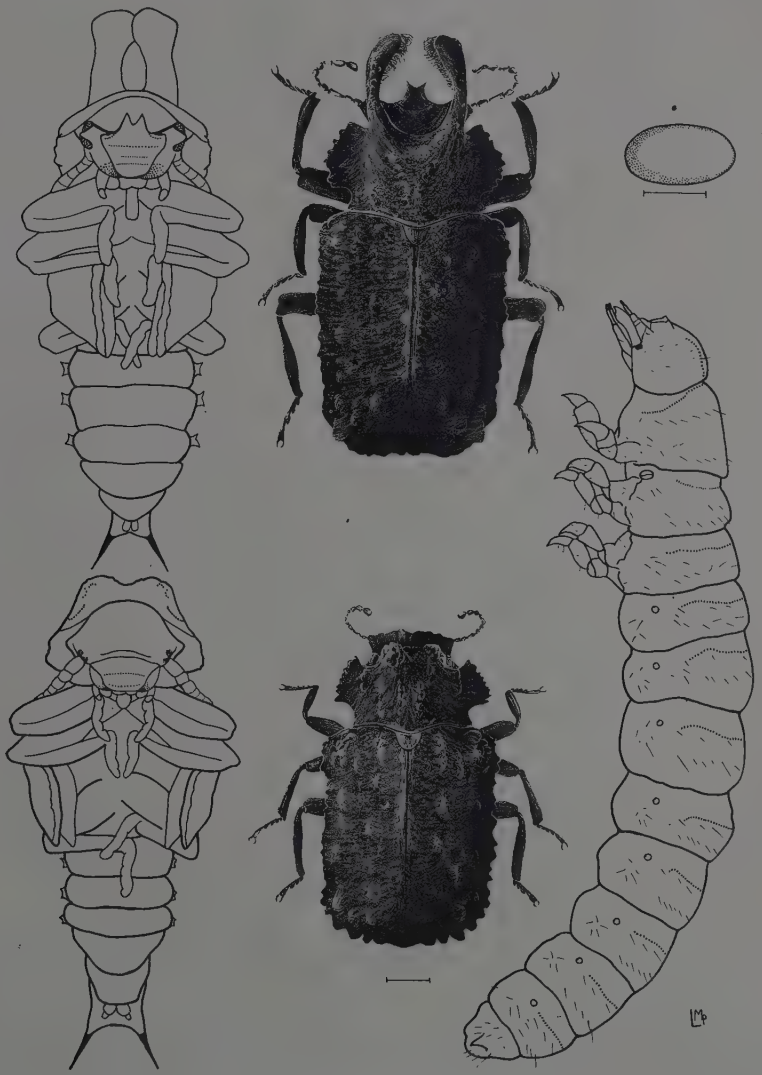

FIGURE 3. *Bolitotherus cornutus* (Panzer). Upper left: male pupa. Lower left: female pupa. Upper center: adult male. Lower center: adult female. Upper right: egg, capsule removed. Lower right: larva. Line indicates 1 mm.

height) and those deposited on the lower surface of the fungus were shorter, narrower and higher (averaged 3.4 mm. in length, 2.1 mm. in width, and 1.8 in height) (fig. 1 and 3).

The larvae were as described by Peterson (1953).

"Form cylindrical, slightly curved, segments distinct and mostly subequal in diameter; color dirty white except cephalic portion of head, mandibles and urogomphi; head prognathous, globular, possessing two, cone-shaped, sclerotized protuberances on frons caudomesad of mandibles; two, contiguous ocelli ventrolaterad of antennae, epipharynx with a single, conspicuous, sclerotized comb-like structure on right half of proximal area; transverse, fine, sclerotized, single lines occur on the cephalic portion of the dorsum of all segments except the prothorax and the ninth abdominal; short, pointed, caudoprojecting urogomphi present on ninth segment; colorless setae present on all areas; spiracles annular with pair on mesothorax oval and two or more times larger than others."

Male pupae had the two slightly curved horns on the thorax which are characteristic of the adult males. Pupae of the females had blunt tubercles on the prothorax which are present in the adult females. The first six abdominal segments of the pupae of both sexes each possessed two pairs of fleshy tubercles on the lateral margins, which ended in small spines. The last abdominal segment possessed a pair of spines. The average length of male pupae was 16.5 mm.; of female, 14.6 mm. (fig. 3).

The adults were as described by Triplehorn (1952).

"Elongate-rectangular, robust; black to reddish-brown, dull, lusterless. Head roughly sculptured, sides elevated; males with bifid horn on clypeus; female with two widely spaced small tubercles on clypeus; antennae 10-segmented, second segment small, third longer than 3 following segments combined, terminal segment globular; eyes deeply emarginate; pronotum roughly sculptured, twice as broad as long, lateral margins broadly flattened, serrate with variable number of rounded teeth; males with 2 slightly curved horns, broader at tip and clothed with yellow hairs beneath, projecting forward from disc of pronotum to well beyond head; females with blunt tubercles instead of horns. Elytra roughly sculptured, each with 4 rows of large irregular tubercles with smaller ones on intervals; abruptly deflected apically; epipleura entire. Ventral surface and legs dull black, lusterless, rugose; males with patch of yellow hairs on inner face of femora; prosternum blunt, horizontal, its apex prominent. Length 10–12 mm.; width 3.5–4 mm." (fig. 3).

SEASONAL HISTORY

B. cornutus was found wintering in both the larval and adult stages. Larvae collected in specimens of *Fomes applanatus* and *Ganoderma tsugae* in Hocking County, Ohio, in February of 1954, were in the third, fourth, and fifth instars. Larvae were also collected on subsequent field trips in March, April, and May. *Fomes applanatus* collected in Cheboygan County, Michigan, early in November, 1954, contained second and third instar larvae.

The adults wintered under the bark of trees, logs, and stumps supporting fungus growth, and also inside the fungi. Wintering adult beetles were collected in Hocking County, Ohio, in February and March of 1954, and in Cheboygan County, Michigan, in November, 1954.

The overwintering adults were apparently responsible for the spring brood of eggs, which, in northern Michigan, were laid from the middle of June until the first of July. Larvae from these eggs completed their development in the fall, and overwintered as adults.

The overwintering larvae completed their development during the early summer, and the resulting adults were responsible for the fall brood of eggs. In northern Michigan, these eggs were laid from the last of July until the middle of September, and the larvae continued to develop until weather conditions were no longer favorable (fig. 4).

Thus, in northern Michigan, there were two apparent egg-laying seasons; one in late spring, and one in early fall. Freshly laid eggs, collected on June 22 indi-

cated that the spring period of egg laying began shortly before this time. Females collected on this date continued to lay eggs in the laboratory until July 2. The following is the oviposition record of the female of a pair of copulating adults collected on June 22:

June 22		one egg
June 23		one egg
June 24		one egg
June 25		one egg
June 26		one egg
June 27		one egg
June 28		no egg
June 29		one egg
June 30		two eggs
July 1		one egg
July 2		no egg
July 3		one egg
July 4		one egg
Total	12 days	11 eggs

These eggs were laid on a specimen of fungus in the laboratory, always between the hours of 5:00 and 7:30 P.M. After July 4, no more freshly laid eggs were observed until July 26, when other females collected on July 19 began to deposit eggs. Freshly laid eggs were collected in the field from August 4 to September 12.

Oviposition records of individual females, and dissections of females collected, indicated that each female probably lays between 8 and 12 eggs.

These eggs were laid singly on the fungus host, mostly on the upper surface in crevices and folds, and along the outer margin. A few eggs were laid on the under or pore surface of the fungus where the new hymenium had not covered that of the previous year. No egg capsules were found on sporulating hymenium.

An egg was first deposited on its side on the fungus, and then covered by the excrement-like material composing the capsule. The female beetle deposited this material around the margin of the egg, and then smoothed it up and over the egg, using the soft, brushlike hairs on the tip of her abdomen. The capsular material was granular when first laid down, but these lumps were completely smoothed over. When first deposited, this capsule was dark, moist, black-brown, but dried to a lighter brown, similar to the color of the supporting fungus surface (fig. 1). The egg capsules on the upper surface of the fungus were noticeably lighter than those on the lower surface. This may be due to the more moist condition of the lower surface.

Eggs of the forked fungus beetle hatched in 11 to 26 days after they were laid, with an average pre-hatching period of 16 days. After hatching, the first instar larvae remained under the egg capsules for an average of 5 days before burrowing into the fungus. During this time, it appeared that the larvae fed on the capsular material, since the fungus beneath the capsule showed no signs of being eaten, and larvae removed from under these capsules had full intestinal tracts. In leaving the egg capsule, the first instar larva either burrowed directly into the fungus, leaving the capsule intact and full of frass, or, bored a small hole in the capsule, crawled out, and migrated over the surface of the fungus for a time before burrowing in. The site of burrowing was generally a crack or crevice in the fungus surface.

After entering the fungi, the larvae constructed tunnels inside the fungus body. These tunnels, unless they were extremely numerous, or unless the fungus had reached a late stage of decay, were not visible from the outside. The first instar larvae constructed small triangular chambers about 2 mm. below the surface. These chambers were approximately 2 mm. by 2 mm. by 3 mm. The first instar larval period lasted from 5 to 15 days with the average being 9.8 days. As the

larvae developed, the chambers were filled with frass and new and larger tunnels and chambers were built. These tunnels either wound down through the fungus or were developed entirely in the upper layer of the fruiting body. Crossing and intertwining of tunnels occurred frequently, but only one larva was present in any particular tunnel.

The average length of the second instar period, during the summer, was 11.3 days; of the third, 44.5 days; and of the fourth, 7 days. These records were made on larvae reared in individual stentor dishes on pulverized fungi in the laboratory during the summer of 1954. In addition to these four instars known to occur in the laboratory, field collections contained an apparent fifth instar. Four instars

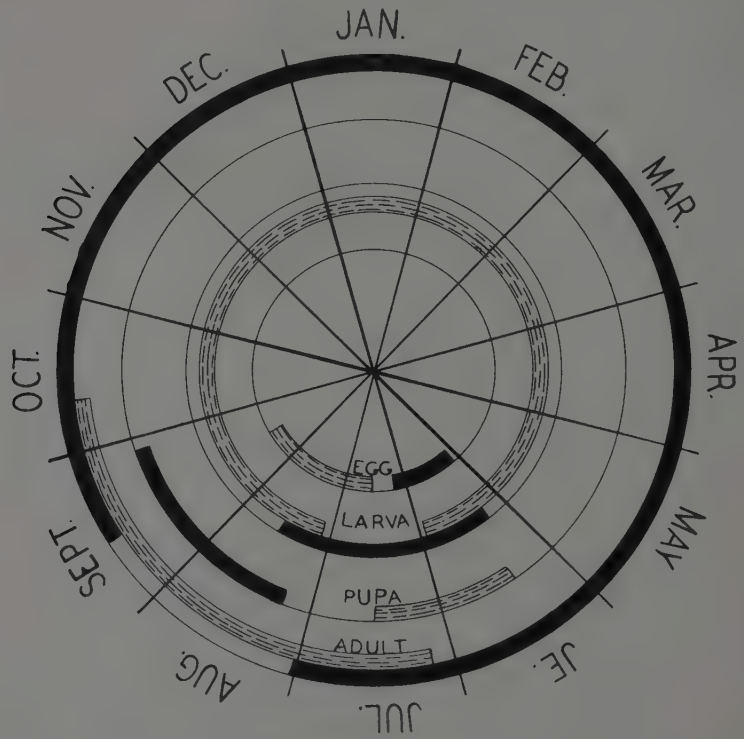

FIGURE 4. A diagram of the annual cycle of *B. cornutus* in northern Michigan. The solid black areas represent one brood, the broken line areas the other.

were present with head capsule measurements equivalent to those of the four instars in the laboratory cultures, but, in addition, fifth instar larvae with head capsules proportionately larger than the fourth instar, occurred in the field collections.

Cast larval skins of all these instars were found in the enlarged chambers in the fungus, but were not found in the connecting tunnels. These chambers were smooth sided and large enough for the larvae to twist about freely. Pupation

occurred in the last of the enlarged larval chambers. The pupae were very active and rotated clockwise and counter-clockwise by rapid thrashings of the abdomen. This movement inside the pupal chamber produced an audible rattling noise. The length of the pupal period during the summer was from 5 to 22 days with an average of 11.6 days.

The adults frequently occupied the pupal chambers for some time after emergence from the pupa. However, never more than one individual occupied each chamber. A larva was observed which had tunneled into the pupal chamber of another individual. The larva had eaten part of the pupa. Such cannibalism was also observed in laboratory cultures in which all the larvae removed from a single fungus were placed in one fingerbowl.

After emerging from the pupal stage, the adults darkened to full color within four days. This period was usually spent in the pupal chamber. The adults escaped from the fungus by chewing through it to the outside. Such emergence holes had a diameter ranging from 6 mm. to 9 mm. and occurred anywhere on the fungus.

TABLE 1

Occurrence of Bolitotherus cornutus (Panzer) in Polyporaceae collected in Cheboygan and Emmet Counties, Michigan, in the summer of 1954

Fungus	No. times Collected	Number containing		
		Egg Capsules	Larvae & Pupae	Adults
Daedalea unicolor	10	0	0	0
Fomes applanatus	63	50	50	49
Fomes fomentarius	5	0	0	1
Fomes ignarius	6	0	0	0
Fomes pinicola	4	0	1	1
Ganoderma tsugae	10	1	4	4
Polyporus adustus	14	0	0	0
Polyporus betulinus	23	0	0	0
Polyporus cinnabarinus	6	0	0	0
Polyporus elegans	3	0	0	0
Polyporus perennis	18	0	0	4
Polyporus versicolor	12	0	0	3

BEHAVIOR

B. cornutus is a nocturnal insect. During the day, the adults were found under the fungi, in old emergence and feeding holes, in the bottom of the fungi, and in crevices in the bark of the tree or log on which the fungi were attached. During the summer, the beetles became active around 8:00 P.M. and this activity continued until about 4:00 A.M. The beetles moved about the fungus a great deal during this time and during this period, feeding and copulation most frequently occurred.

When disturbed, the adult beetles responded with the death feint characteristic of many tenebrionids.

A peculiar behavior pattern apparently connected with mating was observed in the beetles in the field and in laboratory cultures. Prior to mating, the male beetle clasped the female in such a manner that the ventral surface of his abdomen rested on the dorsal surface of her thorax, and the ventral surface of his thorax rested on the dorsal surface of her abdomen. When in this position, the male rubbed the ventral surface of his abdomen across the two prominent tubercles which projected from the female's thorax. This produced a distinct rasping sound audible at a distance of six to eight feet from the fungus. This noise making

was carried on for one or two minute periods interspersed by one or two minutes of quiet. At the end of one of these periods of rasping, the male reversed his position and copulated with the female. This noise making was carried on at different periods for several days before and after copulation, and during the egg laying period. However, the noise was usually produced at night. Pairs of beetles were frequently found in the position for noise making when no noise was being produced.

HOST RELATIONSHIPS

Larvae and adults of *B. cornutus* were observed feeding only on Polyporaceae. The most commonly infested fungus in northern Michigan was *Fomes applanatus* (table 1). The larvae burrowed inside the fungus and fed on the hymenial layers. Tunnels in these layers contained great quantities of excrement. The adults also fed internally in the fungus or on the exposed pore surface on the bottom of the fungus.

Examination of the excrement and gut contents of both larvae and adults showed broken fragments of fungus mycelium, broken and whole fungus spores, and great numbers of bacteria.

In the laboratory, larvae thrived equally well on autoclaved or unautoclaved pulverized fungi.

PARASITOID RELATIONSHIPS

Larvae of *B. cornutus* were attacked by a braconid, *Eubadizon orchesiae* (Ashm.). The wasps' pupal cocoons, covered with light yellow silken threads, were frequently found in old larval tunnels in the fungi. A head capsule of a third instar *B. cornutus* larva was generally found at one end of each cocoon, indicating that the wasp probably completed its larval development during this phase of the host's development. The wasp cocoons averaged 6 mm. in length and 3 mm. in width.

Two female wasps, reared from collected material and released on a fungus covered with egg capsules of the beetle, ran about the surface of the fungus, moving their antennae over it rapidly and poking at it with their ovipositors. Whenever a small hole or crack was found in the fungus, the ovipositor was inserted in it. This was also true of the emergence holes in the tops of some of the egg capsules.

Fomes applanatus collected in the field frequently contained masses of white mycelium in the larval tunnels. Examination of these masses showed that each contained a dead *B. cornutus* larva with its body cavity filled with the mycelium.

SUMMARY

In the region of Cheboygan County, Michigan, the forked fungus beetle, *Bolitotherus cornutus* (Panzer), had one generation per year. The beetle overwintered both as adults and larvae; the adults under bark, the larvae in the fungus host, chiefly *Fomes applanatus*.

Overwintering adults laid eggs in mid June, the resulting larvae completing their development in early fall. The overwintering larvae became adults in mid summer and began ovipositing in late August. The larvae from these eggs developed until weather conditions retarded them.

The eggs were deposited singly on the upper and lower surfaces of the host fungus and were covered with an excrement-like capsule. Each female deposited between 8 and 12 eggs at a rate of 1 or 2 eggs per day.

The larvae bored into the host fungus and tunneled through it during development. Pupation occurred in an enlarged chamber in the larval tunnel.

The larval reared in the laboratory on pulverized *Fomes applanatus* underwent four instars before pupation. Measurements of head capsules of field collected larvae indicated that five instars may occur in nature.

The forked fungus beetle is nocturnal, feeding and mating chiefly at night. A peculiar noise making behavior occurred during the mating season.

A braconid wasp, *Eubadizon orchesiae* (Ashm.) was found in the pupal stage in old larval tunnels, with the head capsule of a third instar beetle larva at one end of its cocoon. *B. cornutus* larvae were also found dead in the center of a white mycelial mass in the larval tunnels.

ACKNOWLEDGMENTS

The author is indebted to the University of Michigan Biological Station, Cheboygan, Michigan, for the use of its facilities and to Dr. H. B. Hungerford for advise on this project during the summer of 1954. Appreciation is also expressed to Dr. R. H. Davidson for his help and advice, and to James S. Bowman for photography.

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A NEW SPECIES OF TYPOCERUS FROM FLORIDA
(COLEOPTERA: CERAMBYCIDAE)

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This new species of *Typocerus* was included in material sent for identification.

Typocerus fulvocinctus n. sp.

Female.—Size and form of *T. aculicauda* Csy.; both surfaces and appendages black with transverse yellow band on basal half near middle of each elytron, band not reaching outer margin, or suture; pubescence black on all but yellow area.

Head with front finely, densely punctate, punctures larger and more widely separated on vertex; antennae extending beyond middle of elytra when laid along side, ratio of lengths of segments 1 to 11, 3:.6:3.4:3:3.4:2.6:2.2:2.2:2.1:1.8:2.4, segments 6 to 10 inclusive with a sunken poriferous area, last segment with two such areas.

Pronotum convex, trapezoidal, hind angles extending over humeri, widest at base; sides rounded in front, then diverging to base; disk with sinuate transverse depression, densely, coarsely punctured, a stiff black hair arising from each puncture. Scutellum triangular.

Elytra near base wider than widest part of pronotum, cuneate; sides rounded in front, then converging to obliquely spinose apices; surface finely punctate, punctures separated by much more than their own diameters, a stout hair arising from each puncture.

Abdomen beneath minutely punctate; first tarsal segment of hind legs much longer than following two segments.

Length 10.6 mm.; width 3.5 mm.

Holotype female collected at Sebring, Fla., April, 1954, by L. A. Hetrick, in collection of author. I am indebted to H. V. Weems, Jr. for the specimen.

The coarse punctures of pronotum together with black pubescence and markings will distinguish this species from any of our described forms.

Typocerus fulvocinctus n. sp. (Line represents 5 mm.)

CLUSTERING OF METEORS AS DETECTED BY THE USE OF RADIO TECHNIQUE

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INTRODUCTION

For the past three years the authors have been observing the effect of meteors on radio propagation by monitoring transmissions from the Bureau of Standards radio station WWV in Washington, D. C. The presence of a meteor was detected by an instantaneous burst of signal strength caused by an oblique reflection from a highly ionized meteor trail. Using this technique it was discovered that clusters of meteors strike the upper atmosphere of the earth.

Observations were made with a conventional short-wave receiver, oscilloscope, and pen recorder. During the early stages of the work, observations were made out-of-doors where sky and equipment could be observed simultaneously and the visual passage of a meteor could be associated with a rapid increase in the field strength of the WWV signal. Coincidence between visual detection and radio detection was established many times during two meteor showers and thirty-four times during one non-shower night. Many bursts were observed on the radio when no meteors were seen. The ratio of radio bursts without visual detection to radio bursts with visual detection was eight to one. This indicated that a much higher rate of meteor detection was available using the radio technique.

During the course of observations several characteristics were noted, as follows: 1. Both radio bursts and visual meteors occurred in clusters. The clusters were separated by periods of time when there was little or no activity. 2. After a cluster had been detected visually and on the radio the signal strength from WWV was greatly increased. The strong signal persisted for anywhere from a few minutes to two hours. 3. During the Perseid shower there was a delay of several seconds between seeing the meteor in the sky and observing the associated burst on the radio. 4. No particular direction of the meteor with respect to the transmitter and receiver locations was required to produce a burst on the radio. The only requirement was that the orientation of the meteor trail should be such that an oblique reflection from the transmitter to the receiver was possible.

The most significant characteristic is the clustering of meteors. A possible theory for the persistence of a strong signal for long intervals of time may be that a cluster strikes the upper atmosphere and the combination of individual ionized columns forms a cloud of ionization which acts as a reflecting medium. Later clusters maintain the ionization. The propagation characteristics associated with the sporadic E layer are then present. If an attempt is made to prove that clusters of meteors produce the characteristic cloud of sporadic E ionization, it must first be proved that meteors strike the upper atmosphere of the earth in clusters. It is the purpose of this paper to prove meteoric clustering.

MEASURING TECHNIQUE

The reception of radio waves transmitted in the 3 to 30 megacycle band at locations remote from the transmitter is highly dependent upon the ionosphere. If a propagation path is to exist between given transmitter and receiver locations, several factors, such as distance between transmitter and receiver, time of day, month, and the phase of the sunspot cycle must be considered. For any given set of conditions there is a theoretical maximum usable frequency which cannot

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be exceeded if a propagation path is to exist. At frequencies higher than the maximum usable frequency the energy penetrates the ionosphere instead of being reflected to the receiver location. If the angle between the incident ray and the normal to the ionospheric surface is increased, the energy is reflected back to the earth, but it returns to the earth at a distance too great for reception at the receiver location. Figure 1 shows the relationship between the various factors at sunspot maximum as accepted for general radio communication. With decreasing sunspot numbers the maximum usable frequency decreases.

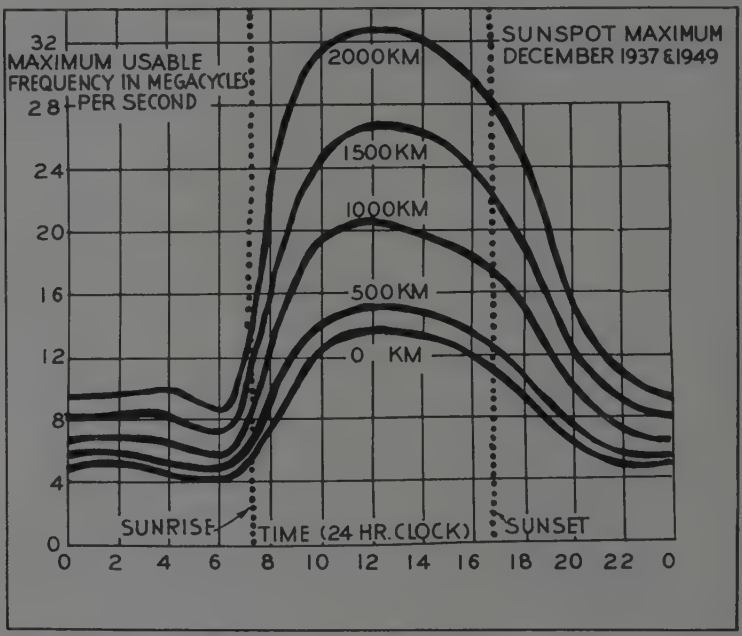

FIGURE 1. Maximum usable frequency at sunspot maximum. Reprinted with permission from "Reference Data for Radio Engineers," 3rd ed. 1949. Federal Telephone and Radio Corporation, New York.

The data for this paper were taken over the 608 kilometer path between Washington, D. C. and Springfield, Ohio. The observations were made between 0200 and 0300 hours. Figure 1 shows that between 0200 and 0300 hours the maximum usable frequency over the 608 kilometer path is about six megacycles at the time of sunspot maximum. The data for this paper were collected using the 20 megacycle signal at less than sunspot maximum. Non-standard conditions caused by localized meteoric ionization made this possible. Lovell (1954) has stated that a representative figure for the degree of ionization present near the E region (100 kilometers) at midnight is 8×10^3 electrons per cubic centimeter. This is the degree of ionization accepted for conditions of standard propagation. Lovell (1954) also stated that with the passage of a meteor the ionization present at the E region is approximately 10^8 electrons per cubic centimeter. This instantaneous rise in ionization has the effect of briefly raising the maximum usable

frequency for a given path by several megacycles. It produces a burst of signal strength that lasts as long as the ionized column will reflect to the receiving station. Figure 2 shows the meteor burst phenomenon. The noise level of the receiver is observed when the effect of the meteor is not present. When a meteor strikes there is an instantaneous rise in signal strength, followed by rapid decay as the column of ionized gas dissipates.

The 20 megacycle signal is the highest frequency on which the WWV signal can be detected over the 608 kilometer path, if an omnidirectional antenna is used. The time required for decay of a burst is less at the higher frequencies than it is at the lower frequencies; consequently, the resolving power of the recording system is better when the higher frequencies are used. Bursts have been detected on the 10 and 15 megacycle signals of WWV; however, since the decay time is greater at the lower frequencies, the saturation point of the recording system is reached sooner than it is on the 20 megacycle signal and the individual bursts cannot be as readily separated.

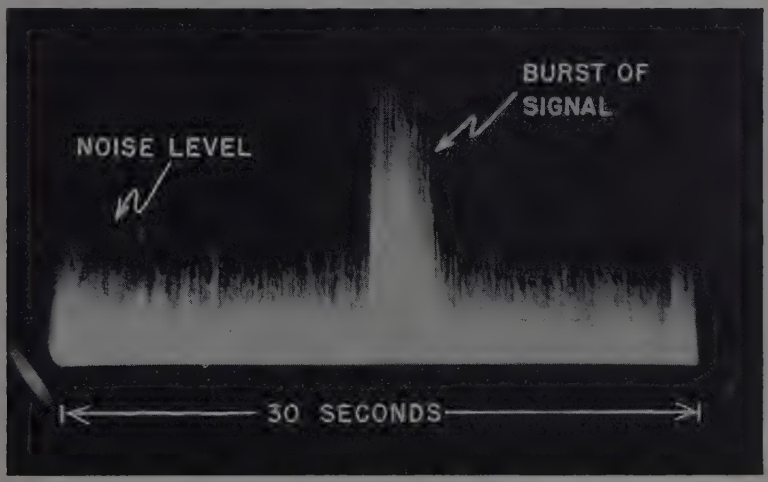

FIGURE 2. Meteor burst phenomenon.

Observations were made from 0200 to 0300 hours because there are more meteors in the morning sky than in the evening sky, and because there is less interference after the TV stations go off the air. Non-shower nights were chosen because the probability of clustering is inherently greater on shower nights than on non-shower nights. Also, on shower nights the recording equipment is frequently saturated for long intervals of time and the individual bursts cannot be detected. Consequently, no observations on shower nights are included in this discussion.

The equipment employed to detect and record meteor bursts is shown in block diagram form in figure 3. The antenna was the long wire type. It was one wave length long and was oriented in the direction of Washington, D. C. It was one-quarter wave length above ground. Because such an antenna has no pronounced directional characteristics, it was possible to observe meteors in all quadrants of the sky. A conventional short-wave type Collins Radio Company model 51J receiver was used. This receiver has the excellent frequency stability characteristics required for the work. At 20 megacycles, less critically designed

receivers have a tendency to drift off frequency, making it impossible to determine whether there were no bursts or whether the receiver was no longer tuned to the transmitting station. Only during bursts can the less critically designed receivers be tuned to the correct frequency. The Collins model 51J can be adjusted in the absence of a signal. The automatic volume control was not used; therefore, rapid changes in the input level of the receiver gave a true indication of the burst amplitude. The audio tone is omitted from the WWV signal during the fourth and fifth minutes of each five-minute interval, but unmodulated energy is still radiated. To obtain data during the fourth and fifth minutes the beat frequency oscillator characteristic of the receiver was used. This injected a signal into the receiver that would mix with the incoming energy and produce an audio tone. Therefore, the tone was present whenever either modulated or unmodulated energy was received. The receiver audio was monitored on a speaker. In order

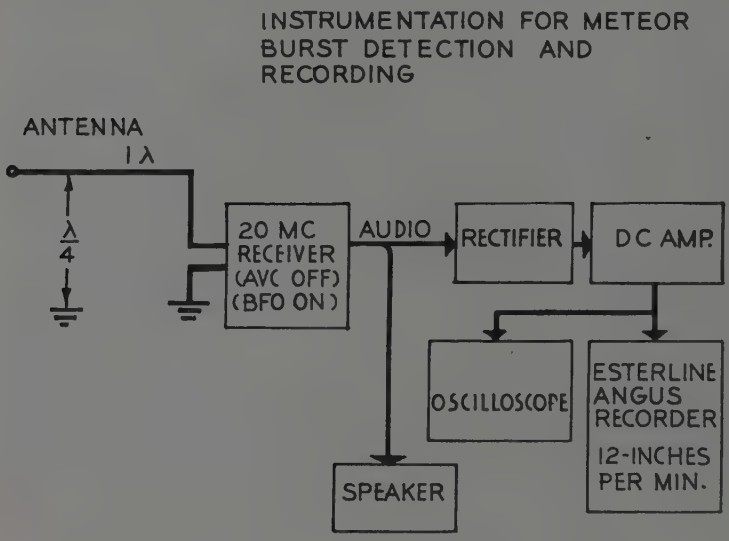

FIGURE 3. Block diagram of meteor detecting and recording system.

to have a permanent record and to establish time relationships between bursts, the receiver audio was rectified using a crystal bridge network amplified by a single stage transistor and applied to a conventional five milliampere Esterline-Angus recorder, which was operated at its highest speed of twelve inches of paper per minute. A marker was placed on the paper each six seconds, a different marker being used to designate the beginning of the minute. In this way the time of each burst became known to the hundredth of a minute.

All information recorded was observed on an oscilloscope. This proved very helpful in eliminating extraneous signals caused by interference from local TV receivers and from power line arcs due to wind and wet weather. The equipment used is shown in figure 4. The second receiver, tuned to the five megacycle signal of WWV, was used to obtain and record the time. With the exception of the recorder, all equipment was of conventional laboratory type. With this equipment it was possible to record as many as fifteen bursts per minute. Figure

5 displays typical recordings of the meteor burst phenomenon. Six intervals of thirty seconds each are shown. The intervals have respectively no bursts, one burst, two bursts, three bursts, four bursts, and five bursts.

EVALUATION OF DATA

The observations of the present discussion were taken on January 10, 1956, and on eight nights thereafter. The discussion includes 1308 meteoric bursts. Bursts were noted at the average rate of 175 per hour, or nearly three per minute. Most of the meteors were doubtless too small and too faint to be seen visually. There was no significant change in rate within the hour. The mean rate for the nine nights was 2.9 bursts per minute for the first five minutes; at 20 to 25 minutes the mean rate was 2.8 bursts per minute; at 40 to 45 minutes the

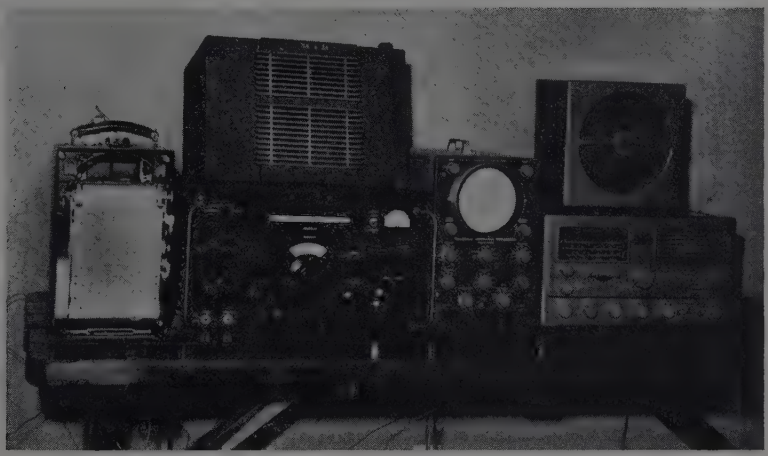

FIGURE 4. Photograph of meteor detecting and recording system.

mean rate was 3.0 bursts per minute; at the close the mean rate was 2.8 bursts per minute. It is seen that there was no diurnal effect within the hour. The variation within the five-minute interval was a little greater than the variations occurring over the hour. The five minute variations ranged from a high of 3.1 bursts per minute during the second and third minutes to a low of 2.5 bursts per minute during the fifth minute of the five-minute intervals. A test by analysis of variance indicates that the variation is without significance. The overall mean interval between bursts was 0.344 minutes, or 20.6 seconds, for the nine nights.

When the hour is divided into a series of equal intervals and the number of bursts per interval is counted, it can be shown that if the bursts are randomly distributed in time the frequency distribution of bursts will follow the Poisson exponential series. A Poisson distribution was fitted to the observed data. One-half minute was chosen as the length of the interval because it was desirable to have intervals short enough that many intervals would have no bursts in them, yet long enough that most intervals would have one or more bursts in them. At 175 bursts per hour the average would be about $1\frac{1}{2}$ bursts per interval.

The observations on nine additional nights were not used. On three of the nights power line arcs due to wind and wet weather caused so much interference

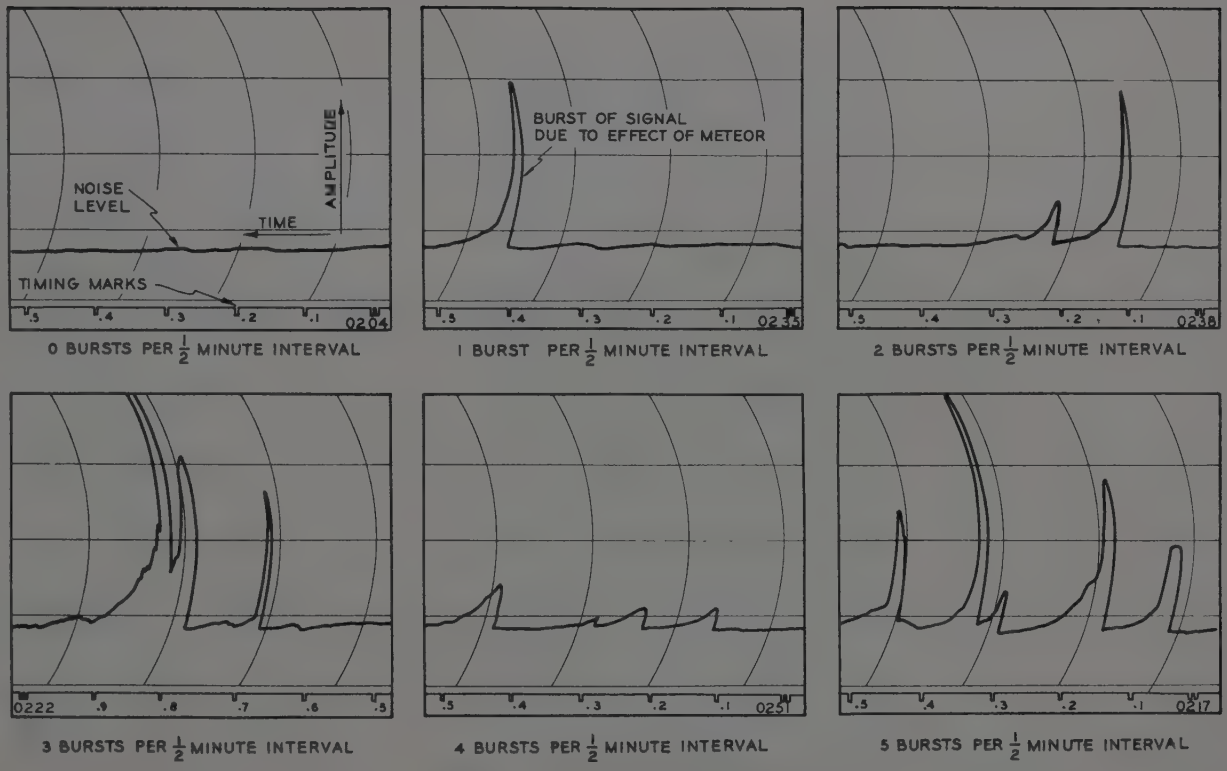
NOISE LEVEL
TIME
AMPLITUDE
TIMING MARKS
.5 .4 .3 .2 .1 0204
0 BURSTS PER ½ MINUTE INTERVAL
BURST OF SIGNAL
DUE TO EFFECT OF METEOR
.5 .4 .3 .2 .1 0235
1 BURST PER ½ MINUTE INTERVAL
.5 .4 .3 .2 .1 0238
2 BURSTS PER ½ MINUTE INTERVAL
0222 .9 .8 .7 .6 .5
3 BURSTS PER ½ MINUTE INTERVAL
.5 .4 .3 .2 .1 0251
4 BURSTS PER ½ MINUTE INTERVAL
.5 .4 .3 .2 .1 0217
5 BURSTS PER ½ MINUTE INTERVAL

FIGURE 5. Typical meteor burst recordings.

that many bursts were obscured. On two nights bursts noted were too few, and on four nights they were too numerous. On the four nights the recording equipment was saturated much of the time, apparently caused by unrecorded showers. An analysis of variance indicated that on the two nights the probability of the occurrence of a burst in a given time interval was significantly low, while on the four nights the probability was significantly high when compared to the probability on the nine nights used.

The first hundred good intervals were used on each night's work. The reasons for not using all good intervals were twofold. On each night some intervals were always lost when large meteors came in and the resulting strong ionization saturated the recording equipment. No additional meteors could be detected until the effect of the large meteor had dissipated. Furthermore, some time between January 16, 1956, and January 21, 1956, the Bureau of Standards ceased to transmit for the five-minute interval from 0245 to 0250, thus eliminating ten intervals. It was impossible to have more than 110 good intervals and the number was always less than that. To achieve balance for all nights, it was decided to use only the first hundred good intervals. The results are shown in table 1.

TABLE 1

Bursts per interval in the first hundred good intervals

Bursts per Interval	Date, 1956									
	1/10	1/14	1/21	1/23	1/31	2/5	2/6	2/19	2/21	Total
0	24	26	26	23	26	20	21	33	24	223
1	36	36	41	33	35	39	39	39	29	327
2	22	22	22	19	19	23	18	16	22	183
3	14	9	6	10	14	10	13	4	18	98
4	3	4	4	4	1	3	6	7	6	38
5	1	2	0	7	3	3	2	0	1	19
6	0	1	1	4	1	2	0	1	0	10
7	0	0	0	0	1	0	1	0	0	2
	100	100	100	100	100	100	100	100	100	900
Total Bursts	139	139	125	176	147	154	155	117	156	1308

Table 1 shows that 25 percent of the intervals had no bursts in them; 36 percent had one burst; and 39 percent had two or more bursts in them. Four or more bursts were in 8 percent of the intervals. The number of intervals having a particular number of bursts did not vary greatly from night to night. The number of bursts in the first hundred good intervals varied from a low of 117 on February 19, to a high of 176 on January 23, so that there was some difference in the probability of the occurrence of a burst in an interval on the different nights. A test by the analysis of variance indicated that the difference in probability was too small to have significance. As was previously shown, there was no significant difference in the probability of a burst as the hour progressed. These two conditions are important since together they imply that the probability of a burst occurring within a given interval is independent of the time. This is an essential requirement for the Poisson distribution.

The theoretical frequency of intervals with no bursts, one burst, two bursts, three bursts, etc., is given by the Poisson exponential series. If the observed frequency of intervals with the various number of bursts closely parallels the Poisson frequency of intervals with the same number of bursts, the distribution of meteors is purely random. A comparison of the observed and Poisson frequencies is given in table 2.

Table 2 shows that the observed frequency is higher than the Poisson frequency at no bursts and at one burst per interval. At two bursts and at three bursts per interval the trend is reversed. At four bursts per interval the observed and Poisson frequencies are about equal. At five bursts per interval and higher, the observed frequencies are appreciably greater.

TABLE 2

Observed and Poisson frequency of intervals with the number of bursts indicated

Bursts per interval	Observed frequency of intervals		Poisson frequency of intervals		(Observed—Poisson)² / Poisson
0	223		210.41		0.753
1	327		305.80		1.470
2	183		222.21		6.919
3	98		107.65		0.865
4	38		39.11		0.032
5	19		11.37		17.770
6	10		2.75		
7	2	31	0.57	14.81	
8	0		0.10		
9	0		0.02		
					$\chi^2 = 27.809$

The last column of table 2 is Karl Pearson's (1900) criterion for determining whether the differences between the observed and Poisson frequency of intervals may be assigned to chance. The quantity chi square is

$$\sum_{1}^{n} \frac{(\text{Observed-Poisson})^2}{\text{Poisson}}$$

and the criterion gives the probability that the series represents fluctuations between the observed and Poisson frequencies that may reasonably be ascribed to random motion. The chi square for this series is 27.809 and the probability that it would result from chance is 0.00003. Not more than three times in 100,000 would a random arrangement produce the observed distribution of bursts. This demonstrates that the observed distribution is not random, and that on non-shower nights many clusters of meteors strike the upper atmosphere of the earth.

It should be recalled that on each night some intervals were rejected because the recording equipment suddenly became saturated and the strong ionization persisted through two or more intervals. The saturations were attributed to large meteors. It is entirely possible that the rejected intervals actually represented sizable clusters of meteors striking the upper atmosphere of the earth. It may well be that the clustering is even more marked than these data show.

The definition of a cluster must be entirely arbitrary. If a cluster is defined as a series of two or more bursts separated by the mean interval of 0.34 minutes or less, there were 186 clusters that entered the earth's atmosphere between 0200 and 0300 hours on the nine nights. The greatest number of meteors in a cluster was 20 and the average number was 4.14. The average duration of a cluster was 34 seconds and the average time between clusters was 1.55 minutes, or 93 seconds. At this stage we cannot say what our results mean as to the number of clusters that enter the earth's atmosphere daily. At present we do not have an opinion on the seasonal and latitudinal characteristics. Present results only show that during the early morning hours on non-shower nights the distribution of meteors striking the upper atmosphere of the earth is not random, but clustered.

Meteoric clusters must represent debris of some sort. The dimming and reddening of remote stars and star clusters indicate that the debris is distributed throughout space, and that most of the particles are very small. The particles of this discussion are the larger meteoric particles, large enough that their motion is controlled by gravity rather than radiation. It would seem that, in the main, the members of such a group would be following the same orbital path, thus indicating a common source for them. Since comets in the solar system are composed of gases and meteoric particles, many of the clusters must be of cometary origin. Due to the operation of Kepler's third law the swarm of particles in the head of the comet would, in time, be spread all the way around the orbit, and each year, when the earth comes close to the comet orbit, some of the particles would be drawn to the earth. Fragmentary groups of particles from extinct comets would also contribute to the influx of meteoric clusters. No one knows the origin of comets but their number is thought to be very great, so that the earth can be close to cometary orbits at all times. There is no generally accepted theory for the origin of meteoric particles. We cannot say how the clusters came into being, but observations show that they exist.

SUMMARY

The presence of meteors striking the upper atmosphere of the earth was detected by monitoring the 20-megacycle transmission of the National Bureau of Standards radio station WWV in Washington, D. C. over a 608 kilometer path. A meteor produces an ionization column which results in a burst of signal strength that cannot be explained by normal ionospheric propagation theory. A statistical study of the meteoric bursts occurring between 0200 and 0300 hours shows that the distribution of bursts is not random, but clustered. Visually noted clusters have been followed by the formation of sporadic E-type propagation. It is suggested that the ionized columns of a cluster unite to form a cloud of ionization, thus making possible the use of higher radio frequencies for more distant communication than would otherwise be possible. Observations show that meteoric clusters exist, but the origin of the clusters is not known.

ACKNOWLEDGMENTS

The authors wish to express their appreciation for the continued interest and helpful advice of Dr. Paul B. Taylor, consultant for Radio Wave Propagation, and of Dr. H. Leon Harter and Mary D. Lum, mathematicians of the Aeronautical Research Laboratory, all of the Wright Air Development Center at Dayton, Ohio. Without their encouragement and counsel this work would not have been done.

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Physical Organic Chemistry. *Jack Hine.* McGraw-Hill Book Company, Inc., New York. 1956. xiv+497 pp. $9.00.

This book is organized into four parts: basic principles (92 pages), polar reactions (283 pages), free radical reactions (75 pages), and four-center type reactions (28 pages). Thus, the book attempts to cover in its 465 pages of text, the modern explanations for the behavior of organic chemical substances. In this, it is probably more successful than any other recent book on this subject. The book is quite capably written and approaches many of the topics from a critical point of view. The organization and readability are good and references to the original literature are numerous. Very few errors in text or typography were spotted by this reviewer. The main criticism that can be leveled at this book is one which would be expected for a work with this wide a field of subject matter and brevity in physical size—that criticism is that in many places the treatment is quite superficial. However, this criticism does not greatly affect the wide use this book will find as a textbook in graduate organic chemistry courses and as a reference. This excellent book can be recommended as a good addition to any chemist's library.

WILLIAM N. WHITE.

General Botany. *W. T. Taylor* and *R. J. Weber.* D. Van Nostrand Co., Inc., Princeton, N. J. 1956. vii+376 pp. $5.75.

The book, according to the authors, was designed for use in an introductory, one-semester course embodying a physiological approach to the study of plants. It seems doubtful that these objectives were attained. Some botanists will feel that the level of presentation of some subjects is rather advanced. Basically the organization of the book seems to be taxonomic with well over one-half the text pages devoted to anatomy and morphology, especially of the lower groups. Emphasis seems to be on details and unnecessary terminology rather than on basic concepts and an understanding of the interrelationships of heredity, environment, processes, structure, and reproduction. Chapter subjects often seem to be treated as entities with a lack of continuity from one to the next. The illustrations are quite good but most of them are drawings.

R. A. POPHAM.

Present-Day Psychology. *A. A. Roback,* Ed. New York: Philosophical Library, Inc. 1955. xiv+995 pp. $12.00.

This book is offered as the most comprehensive survey of contemporary psychology available in English today. That it ranges far in its coverage of psychological topics cannot be denied; whether it is representative of what is being done is something else again. American behaviorists will thus be amused to find that conditioning and related theories have no place in such a collection, even though a chapter is given to a survey of histories of psychology. Topics with the best empirical foundations come off second best; Harry Stack Sullivan seems to require almost twice as much discussion as the whole field of sensory processes. There are, of course, ample resumés of progress in these areas, and hence little harm is done so long as the volume stays out of the hands of the unwitting. To them, it would give a grossly false impression of the psychological status quo.

What can we expect of an expert who is asked to review the major facets of a field in the space of a few short pages? This is the dilemma for any encyclopaedist, and the success of his work depends upon his skill in defining the task. If the discussions are to warrant the attention of a specialist, they are at best annotated bibliographies. This result is admirably achieved by several of the book's contributors, and their papers make it well worth owning. As we might expect, however, there is substantial qualitative variation. *Present-day Psychology* will not be remembered as a milestone in the literature, but it is a useful guide, and particularly so as an introduction to ways of thinking that are somewhat uncommon in this country.

DONALD R. MEYER.

Classics of Biology. *August Pi Suñer.* Translated from the Spanish by *Charles M. Stern.* Philosophical Library, Inc. New York. 1955. x+337 pp. $7.50.

This book is a review of selected controversies of historical interest to the biologist and others interested in the development of scientific ideas. However, it is much more than a list of names and dates. It is not only a chronology of ideas, but also an interpretation of those ideas. While we must recognize that there is much to be learned from the errors of our predecessors, fortunately this book indulges in a minimum of dwelling on the mistakes of early workers.

Throughout the book there is repeated emphasis on the relationship between cause and effect; between form and function. Also recurrent are the ideas that the whole is more than the sum of its parts, and that there is a purpose to life, but each individual is only incidental to that purpose. Some interpretations are surprisingly non-mechanistic in view of the author's background in physiology. One might criticize the author's choice of certain words, *e.g.* ". . . the microgamete . . . *seeks out* . . . the macrogamete." There are, also, many long, complex sentences in which ideas are difficult to follow. There is much in the book that will be of value to the teacher and the serious student in elucidating the historical development of ideas.

ROBERT M. CROWELL.

THE WINTER-GREEN HERBACEOUS FLOWERING PLANTS OF OHIO[1]

JANICE C. BEATLEY

Department of Botany and Plant Pathology, The Ohio State University, Columbus 10

Nearly everyone is familiar in some way with plants which are green in winter in the Deciduous Forest region. The evergreen conifers, especially the pines, spruces, firs and cedars, planted extensively for landscape purposes, are probably the most widely recognized. In fact, the terms evergreen and conifer are commonly used by the layman as synonyms. Winter wheat, and the bluegrass and dandelions of lawns are likewise familiar species which add greenness to landscapes in a season when the leaves of most plants have withered and died. Overwintering leaves of candytuft, foxglove, sweet william, chrysanthemum, and others are well-known to gardeners and nurserymen. Botanists have long been aware of the winter-green leaves of such shrubs as *Rhododendron*, *Kalmia*, and others of the Heath Family, as well as the frequency of winter-greenness among ferns, and the conspicuous greenness of mosses, as a group, in the winter aspect of almost any forest.

During the months of November through February, however, when snow cover is absent, there is a large population of green herbaceous plants in field and forest which appear little or none the worse for the presumed rigors of the season. Far from being devoid of herbaceous plants in the winter, the ground is dotted with green nearly everywhere. This population consists of many different kinds of plants, and the species, genera, or families to which they belong often cannot be ascertained by the usual vegetative characters customarily used in their identification. These are the plants with which this paper is concerned.

Earl (1907) noted that a number of species in Ohio are winter-green in addition to conifers and woody dicots. In her compilation 16 genera and 27 species of herbaceous angiosperms are cited. She classed *Glechoma hederacea* and some species of *Lamium* among the most hardy of herbaceous perennials, the genera *Senecio*, *Taraxacum*, and *Achillea* among the more hardy of the winter-green rosette plants, and such species as *Poa pratensis* and *Nepeta cataria* among those which partly withstand freezing. Of this list, one species (*Sempervivum tectorum*) is strictly cultivated, three are not known to occur in Ohio from The Ohio State University herbarium records (*Moneses uniflora*, *Pyrola asarifolia* and its variety *purpurea*), and one is considered to be very doubtfully winter-green (*Malva rotundifolia*).

Griggs (1914) classified the evergreen plants in the Sugar Grove region of Ohio in three groups: (1) "Typical shade-loving evergreens with leaves appearing late in the season", consisting of *Goodyera pubescens*, *Pyrola elliptica*, and *Epigaea repens;* (2) "shade-loving herbs with hibernating leaves replaced in spring by new ones", represented by *Hepatica acutiloba*, *H. americana*, *Carex plantaginea*, *Tiarella cordifolia*, and *Maianthemum canadense;* and (3) "evergreen herbs with leaves or shoots ascending sufficiently from the ground partially to surmount a blanket of fallen leaves", in which *Mitchella repens* and *Gaultheria procumbens* are the flowering species cited.

There apparently has been no attempt made, in North America at least, to list comprehensively the winter-green species of any geographical area, to describe these species in the winter condition, or to devise keys by which they may be

[1]Publication 564, Department of Botany and Plant Pathology, The Ohio State University.

identified in winter. Lidforss (1907) enumerated more than 130 winter-green central and northern European vascular species growing in the Botanical Gardens at Lund, Sweden, which were used in his chiefly physiological studies of winter-green plants. More recently Nilsson (1949) has observed degrees of winter hardiness exhibited by over 4,200 ornamental herbaceous species growing in Sweden.

The standard manuals of Fernald (1950) and Gleason (1952) make only occasional reference to species as being winter-green. A rather large number of introduced weed species are described as "winter annuals" in the weed manuals of Muenscher (1935) and Georgia (1923), covering the ranges of *Gray's Manual* and *Britton and Brown's Illustrated Flora*, and in various publications encompassing the weed floras of more limited areas. Mention of perennial species which are winter-green, in treatises of any kind dealing with the taxonomy, ecology, or physiology of flowering plants, is rare, and descriptions of winter annuals or winter-green perennials in the winter condition are essentially non-existent.

SOURCES OF DATA

During the winters of 1945–48, more than 1,000 herbaceous winter-green plants were selectively collected in the field and transplanted in clay pots. Thereafter some were placed in cold frames in The Ohio State University Botanical Garden, duplicate specimens were placed in the greenhouse, and triplicate specimens, when collected, were retained for the herbarium. As these plants flowered and fruited, they were identified and the determinations checked with specimens in The Ohio State University herbarium. Although a number of problems were encountered in maintaining this extremely diverse population in such a manner that anthesis might occur in all, determinations were ultimately made of all but a half-dozen or so plants. After the first year, collections were made between mid-December and the last of February since it became evident the first winter that for many of our native species there is a cold period requirement, necessary for the breaking of winter dormancy, which is not fulfilled in this region until sometime in December.

Collections were made by habitat, and such habitats as seemed most likely to contain chiefly native flora were the principal collecting areas. The most extensive collections were made in the Hocking Hills of Fairfield and Hocking Counties, Ohio, because of the region's great diversity of habitats and richness of flora. The winter herbaceous flora of the Oak and Mixed Mesophytic communities of this region is considered to be representative of these communities throughout most of the Allegheny Plateau of eastern and southern Ohio. Collections were also made in Beech-Sugar Maple forests in central Ohio, and in swamp forests, prairies, bogs, old field communities, and on pioneer sites in both central and southern Ohio. A number of stands of all of the principal forest types of central and southern Ohio were visited over the three-year period, and it is believed that most, if not all, of the winter-greens which are at all common in forest communities of this part of the State were collected. The flora of the upland forests was relatively more thoroughly studied than the more diverse flora of some of the swamp forest types. Likewise forest species were more intensively collected than species of pioneer communities or other sites on which various stages of succession were occurring.

THE WINTER-GREEN FLORA

In the list which follows are included all flowering plant species (excepting shrubs) which are known from the present field study to be green throughout the winter in central and southern Ohio. Such species as *Saponaria officinalis*, in which many of the leaves often remain green until midwinter but have obviously been so severely injured that recovery will not ensue, have not been included.

Species referred to as "winter annuals" by Muenscher (1935), Georgia (1923), or Runnels and Schaffner (1931), which were not collected during this investigation but which are known to occur in Ohio from records of The Ohio State University herbarium, have also been included; these are marked with an asterisk—almost all are Eurasian weed species, many of which are rare or have restricted distributions in the State at the present time. Except for three species, the Panicums have been included on the authority of Hitchcock and Chase (1950), who characterize the group to which these Ohio species belong as having "basal leaves usually distinctly different from those of the culm, forming a winter rosette." A few other species are included on the authority of other authors, and are so designated by citation of their publications. Synonymy and phylogenetic order are essentially those of Fernald (1950).

It is not presumed that the list includes all of the herbaceous angiosperms which regularly have green, living leaves throughout the winter in Ohio. Grasses, sedges, and rushes were collected only occasionally, and these families without question, on the basis of field observations, are only partially represented. Several members of the Labiatae remain unidentified because of failure of anthesis under greenhouse or cold frame conditions, and it seems probable that a number of additional species in this family will be demonstrated to be winter-green. Representatives of the Cruciferae in the present list are largely the "winter annuals" of the weed manuals, and the native biennial and perennial winter-green mustards are doubtless not well represented in this compilation. The present list, consisting of 287 species, represents about 16 percent of Ohio's herbaceous flowering species. It is anticipated that the percentage will be no less than 20 when the list is more nearly complete.

Gramineae
Bromus kalmii Gray
B. secalinus L.*
B. japonicus Thunb.*
B. mollis L.*
B. sterilis L.*
B. tectorum L.*
Poa pratensis L.
Hordeum jubatum L.*
Elymus virginicus L.
Hystrix patula Moench
Deschampsia caespitosa (L.) Beauv.
Danthonia spicata (L.) Beauv.
Agrostis perennans (Walt.) Tuckerm.
Cinna arundinacea L.
Panicum linearifolium Scribn.
P. bicknellii Nash
P. microcarpon Muhl.
P. boreale Nash
P. dichotomum L.
P. yadkinense Ashe
P. meridionale Ashe
P. lanuginosum Ell.
P. villosissimum Nash
P. columbianum Scribn.
P. sphaerocarpon Ell.
P. polyanthes Schultes
P. malacophyllum Nash
P. oligosanthes Schultes
P. leibergii (Vasey) Scribn.
P. xanthophysum Gray
P. commutatum Schultes
P. clandestinum L.
P. latifolium L.
P. boscii Poir.
Andropogon virginicus L.

Cyperaceae
Carex plantaginea Lam.
C. platyphylla Carey
C. gracilescens Steud.

Juncaceae
Juncus effusus L.
Luzula acuminata Raf.
L. campestris (L.) DC.

Liliaceae
Chamaelirium luteum (L.) Gray
Allium vineale L.

Iridaceae
Iris virginica L.

Orchidaceae
Goodyera pubescens (Willd.) R. Br.
Aplectrum hyemale (Muhl.) Torr.

Polygonaceae
Rumex crispus L.
R. obtusifolius L.
R. acetosella L.

Portulacaceae
Claytonia virginica L.

Caryophyllaceae
Scleranthus annuus L.*
Spergula arvensis L.*
Arenaria serpyllifolia L.
Stellaria media (L.) Cyrillo
S. longifolia Muhl.
Cerastium vulgatum L.
C. arvense L.*
C. nutans Raf.
C. viscosum L.
Agrostemma githago L.
Lychnis alba Mill.
Silene antirrhina L.
S. dichotoma Ehrh.*
S. noctiflora L.*
S. caroliniana Walt. (Braun, 1928)
S. virginica L.
S. rotundifolia Nutt.
Dianthus armeria L.

Nymphaceae
Nuphar advena (Ait.) Ait. f.

Ranunculaceae
Ranunculus sceleratus L.*
R. abortivus L.
R. recurvatus Poir.
R. septentrionalis Poir.
Hepatica americana (DC.) Ker
H. acutiloba DC.
Anemone virginiana L.
Isopyrum biternatum (Raf.) T. & G.
Coptis groenlandica (Oeder) Fern. (Fernald, 1950)
Aquilegia canadensis L.

Papaveraceae
Chelidonium majus L.
Argemone mexicana L.*
Corydalis flavula (Raf.) DC.

Brassicaceae
Draba cuneifolia Nutt.*
D. reptans (Lam.) Fern.*
D. verna L.
Berteroa incana (L.) DC.*
Thlaspi arvense L.*
T. perfoliatum L.*
Lepidium campestre (L.) R. Br.
L. virginicum L.
L. densiflorum Schrad.*
Coronopus didymus (L.) Sm.
Capsella bursa-pastoris (L.) Medic.
Camelina sativa (L.) Crantz*
C. microcarpa Andrz.*
Neslia paniculata (L.) Desv.*
Raphanus raphanistrum L.*
Brassica juncea (L.) Coss.*
B. nigra (L.) Koch*
B. rapa L.*
Conringia orientalis (L.) Dumort.*
Alliaria officinalis Andrz.*
Sisymbrium officinale (L.) Scop.*
S. altissimum L.*
Arabidopsis thaliana (L.) Heynh.
Descurainia pinnata (Walt.) Britt.*
Erysimum cheiranthoides L.*
E. repandum L.*
Rorippa islandica (Oeder) Borbas
Nasturtium officinale R. Br.
Barbarea vulgaris R. Br.
B. verna (Mill.) Aschers.
Cardamine bulbosa (Schreb.) BSP.
C. douglassii (Torr.) Britt.
C. pensylvanica Muhl.
Arabis patens Sulliv.
A. laevigata (Muhl.) Poir.

Crassulaceae
Sedum acre L.
S. ternatum Michx.
S. telephium L. (Earl, 1907)
S. telephioides Michx. (Earl, 1907)

Saxifragaceae
Saxifraga virginiensis Michx.
S. pensylvanica L.
Tiarella cordifolia L.
Heuchera americana L.
Mitella diphylla L.
Chrysosplenium americanum Schwein.

Rosaceae
Fragaria virginiana Duchesne
Potentilla recta L.
P. norvegica L.
P. intermedia L.
P. simplex Michx.
Geum canadense Jacq.
G. virginianum L.
G. vernum (Raf.) T. & G.
Agrimonia gryposepala Wallr.
A. parviflora Ait.

Leguminosae
Trifolium pratense L.
T. repens L.
T. hybridum L.
Medicago lupulina L.
Vicia sativa L.*
V. angustifolia Reichard*
V. caroliniana Walt.
V. villosa Roth

Callitrichaceae
Callitriche heterophylla Pursh

Guttiferae
Hypericum punctatum Lam.
H. mutilum L.

Cistaceae
Lechea racemulosa Lam.
Violaceae
Viola papilionacea Pursh
V. sagittata Ait.
V. triloba Schwein.
V. blanda Willd.
V. striata Ait.
V. conspersa Reichenb.
V. rostrata Pursh
Cactaceae
Opuntia humifusa Raf. (Earl, 1907)
Onagraceae
Epilobium coloratum Biehler
E. glandulosum Lehm.
Oenothera biennis L.
Gaura biennis L.
Umbelliferae
Sanicula gregaria Bickn.
Chaerophyllum procumbens (L.) Crantz
Osmorhiza claytoni (Michx.) C. B. Clarke
O. longistylis (Torr.) DC.
Torilis japonica (Houtt.) DC.
Zizia aurea (L.) W. D. J. Koch
Cryptotaenia canadensis (L.) DC.
Thaspium trifoliatum (L.) Gray
T. barbinode (Michx.) Nutt.
Heracleum maximum Bartr.
Daucus carota L.
Pyrolaceae
Chimaphila umbellata (L.) Nutt.
C. maculata (L.) Pursh
Pyrola secunda L. (Fernald, 1950)
P. elliptica Nutt.
P. rotundifolia L.
Ericaceae
Epigaea repens L.
Gaultheria procumbens L.
Primulaceae
Trientalis borealis Raf. (Earl, 1907)
Samolus parviflorus Raf.
Lysimachia nummularia L.
L. ciliata L.
Gentianaceae
Sabatia angularis (L.) Pursh
Obolaria virginica L.
Apocynaceae
Vinca minor L.
Polemoniaceae
Polemonium reptans L.
Phlox divaricata L.
P. stolonifera Sims
P. paniculata L.
Hydrophyllaceae
Hydrophyllum canadense L.
H. appendiculatum Michx.
Phacelia purshii Buckl.
Boraginaceae
Lithospermum arvense L.*
Myosotis scorpioides L.
Lappula echinata Gilib.*
Labiatae
Glechoma hederacea L.
Prunella vulgaris L.
Leonurus cardiaca L.
Lamium amplexicaule L.
L. purpureum L.
L. maculatum L. (Earl, 1907)
L. album L. (Earl, 1907)
Salvia lyrata L.
Blephilia ciliata (L.) Benth.
B. hirsuta (Pursh) Benth.
Scrophulariaceae
Verbascum thapsus L.
V. blattaria L.
Veronica serpyllifolia L.
V. officinalis L.
V. peregrina L.*
V. arvensis L.
V. agrestis L.*
V. persica Poir.*
Castilleja coccinea (L.) Spreng.
Plantaginaceae
Plantago major L.
P. rugelii Dcne.
P. lanceolata L.
P. aristata Michx.*
P. virginica L.
Rubiaceae
Galium aparine L.
G. triflorum Michx.
G. pilosum Ait.
Mitchella repens L.
Houstonia caerulea L.
H. longifolia Gaertn.
H. canadensis Willd.
Caprifoliaceae
Linnaea borealis L. (Fernald, 1950)
Valerianaceae
Valerianella olitoria (L.) Poll.*
V. intermedia Dyal
Dipsacaceae
Dipsacus sylvestris Huds.
Campanulaceae
Campanula americana L.
Lobelia cardinalis L.
L. siphilitica L.
L. spicata Lam.
L. inflata L.

Compositae
Solidago caesia L.
S. flexicaulis L.
S. erecta Pursh
S. patula Muhl.
S. juncea Ait.
S. nemoralis Ait.
S. rugosa Ait.
S. gigantea Ait.
S. rigida L.
Aster divaricatus L.
A. macrophyllus L.
A. cordifolius L.
A. undulatus L.
A. prenanthoides Muhl.
A. puniceus L.
A. laevis L.
A. pilosus Willd.
A. lateriflorus (L.) Britt.
A. tradescanti L.
Erigeron pulchellus Michx.
E. philadelphicus L.
E. annuus (L.) Pers.
E. strigosus Muhl.
E. canadensis L.*
Antennaria plantaginifolia (L.) Hook.
Gnaphalium obtusifolium L.
G. purpureum L.
Polymnia canadensis L.
Rudbeckia laciniata L.
R. triloba L.
R. hirta L.
R. speciosa Wend.
Achillea millefolium L.
Anthemis cotula L.*
Matricaria maritima L.*
M. chamomilla L.*
Chrysanthemum leucanthemum L.
Senecio vulgaris L.*
S. aureus L.
S. obovatus Muhl.
Cirsium vulgare (Savi) Tenore
C. altissimum (L.) Spreng.
Centaurea cyanus L.*
Taraxacum officinale Weber
Lactuca scariola L.
L. canadensis L.
L. floridana (L.) Gaertn.
L. biennis (Moench) Fern.
Hieracium venosum L.
H. paniculatum L.
H. gronovii L.

Vegetative form. Differences in degree of elongation of the internodes of the overwintering above-ground stems are responsible for the most pronounced differences in vegetative form. In most cases, the internodes are quite distinctly either elongated or not elongated.

Where internodes are clearly elongated, leaves are distinctly opposite, alternate, or whorled along the length of the stem. Stems may be branched or simple, and erect, ascending, decumbent, or prostrate. The terminal bud is rarely more than eight and usually less than five centimeters above ground. To this group belong the species of the following: *Cerastium*, *Sedum*, Leguminosae, *Epigaea*, *Gaultheria*, *Lysimachia* (*nummularia*), *Obolaria*, *Phlox*, Labiatae (except *Prunella* and *Salvia*), *Veronica*, Rubiaceae, *Chrysosplenium*, *Hypericum*, *Lechea*, and *Polymnia*. In a few cases, *e.g.*, *Chimaphila* spp., stems are elongate but the leaves are crowded near the tip, and in *Claytonia* there are but two leaves borne at the end of a fragile usually non-green stem which is several centimeters long. In *Houstonia caerulea*, stems are frequently highly branched forming a polster. For the most part, the vegetative form and vegetative characters of plants belonging to this group are essentially like those at other seasons of the year.

Where the internodes are not appreciably elongated, the leaves are crowded on short simple usually erect stems and may be ascending or prostrate. If the petioles are margined and shorter than the blades, and the leaves are prostrate and in a more or less radially symmetrical arrangement the plants are here referred to as having a rosette form. If the petioles are unmargined or margined and longer than the blades, or the leaves are not in a radially symmetrical arrangement, or they are ascending, the plants are said to have a tufted form. In both rosettes and tufts, the terminal bud is usually less than two centimeters above ground and the leaf arrangement is not readily evident. The short stem usually bears a few to several or many leaves; exceptions are *Aplectrum*, where there is but a single leaf, and *Solidago juncea* where usually only two principal leaves are present. Leaves of both rosettes and tufts are often quite different from those which appear on the elongated stems during the following growing season and are those which, when still persistent at time of flowering, are sometimes referred to in taxonomic works as the "basal leaves."

Species with well-developed flat rosettes are those of the following genera and families: *Goodyera*, Cruciferae (most), *Arabis* (*laevigata*), *Saxifraga* (*virginiensis*), *Agrimonia*, *Epilobium*, *Sabatia*, *Verbascum*, *Castilleja*, Plantaginaceae, *Dipsacus*, *Lobelia*, *Antennaria*, *Gnaphalium*, *Cirsium*, and *Lactuca*.

Tufted forms include: Gramineae, Cyperaceae, Juncaceae, Liliaceae, *Rumex*, *Dianthus*, *Corydalis*, Ranunculaceae, *Cardamine*, *Tiarella*, *Heuchera*, *Mitella*, *Fragaria*, *Potentilla*, *Viola*, Umbelliferae, *Pyrola*, *Lysimachia* (*ciliata*), *Polemonium*, *Hydrophyllum*, *Valerianella*, *Campanula*, *Aster*, *Solidago*, *Rudbeckia*, *Chrysanthemum*, and *Senecio* (*aureus*).

Species which are often difficult to classify as having either distinct rosettes or tufts are those of *Silene*, *Saxifraga* (*pensylvanica*), *Geum*, *Oenothera*, *Gaura*, *Salvia*, *Erigeron* (*annuus*), and *Hieracium*. In some, *e.g.*, *Phacelia*, *Leonurus cardiaca*, and *Houstonia* (*caerulea*, *longifolia*, and *canadensis*), the degree of internode elongation is variable. Watercress (*Nasturtium officinale*) is singular in that during much of the winter season individuals have elongated internodes, but by mid-February this population at least sometimes has been replaced by one consisting of distinct rosettes.

Approximately 47 percent of the species cited here as being winter-green occur as tufts; 23 percent have a rosette form; 20 percent have elongated internodes; six percent occur as either tufts or rosettes; and four percent may have elongated internodes or not, depending apparently upon environmental conditions during the autumn and winter seasons.

Time of appearance of the winter leaves. The winter-green species are biennials and perennials: 73 percent are perennials, 35 percent biennials, and two percent biennials and under certain conditions perennials. Examples of the last group are *Rudbeckia triloba*, *Lychnis alba*, *Ranunculus abortivus*, and *Oenothera biennis*, specimens of all of which were perennial for four years or longer in the Botanical Garden. Species described in weed manuals and other publications as "winter annuals" have life cycles spanning two growing seasons, and hence are biennials in the sense that a biennial is one in which germination of the embryo takes place during one growing season and flowering and death occur in the subsequent growing season.

The overwintering leaves of biennials (and first-year perennials) apparently are those formed during summer or autumn growth following germination of the embryo. The winter leaves may persist at the time of flowering, although usually by this time they have disappeared or are present only as remnants.

Perennials exhibit a wide range of variation in time of appearance of the overwintering leaves. In some of the spring-flowering species, *e.g.*, *Hepatica* spp. and *Saxifraga virginiensis*, the leaves which will overwinter appear during flowering or shortly thereafter, and persist until the following spring. In others, *e.g.*, *Cardamine bulbosa* and *Isopyrum biternatum*, the old winter leaves die by early summer along with the spring growth, and new winter leaves appear during the autumn. This growth regime, characterized by the presence of leaves in the autumn, winter and spring months is found, with variations in the time of appearance and death of the leaves, in a number of other species, *e.g.*, *Claytonia virginica*. In this species the winter leaves begin growth in early winter and continue until time of flowering in April, after which death of the above-ground parts occurs.

In a number of spring-flowering species, the summer and winter leaves have essentially the same appearance, and the latter are apparently merely those which are present when the winter season commences. Examples of this group are *Sedum ternatum*, *Fragaria virginiana*, and *Houstonia caerulea*. Winter leaves of such summer-flowering species as *Potentilla* spp. and *Lysimachia nummularia* also do not appear to be the result of growth occurring during a period specifically related to the time of flowering or to the changing autumn environment.

In still others among the spring-flowering species, *e.g.*, *Viola* spp., the winter leaves appear at a definite time in late summer or autumn, accompanied by death of the summer leaves.

Among summer- and autumn-flowering perennial species, the winter leaves first appear by far most frequently during flowering or soon thereafter, continue growth as long as favorable environmental conditions prevail, and persist until the following spring or in some cases into summer. All such tufts or rosettes are in reality branches arising from buds usually near the below-ground base of the old stem—"basal offshoots" of some authors—and the time of formation

of these vegetative buds (or those of spring-flowering species as well) is unknown in most cases. Examples of this group are *Aster* and *Solidago* spp., *Rudbeckia* spp., *Lobelia* spp., and *Anemone virginiana*.

The overwintering leaves of both biennials and perennials are frequently distinctly different in appearance from the leaves present at other seasons. In other cases they are similar but at variance in some respects, and in still others the overwintering leaves are indistinguishable from those of other seasons. These seasonal differences have been described only in isolated instances, even monographers usually failing to mention them. A notable exception is the treatment of the genus *Heuchera* by Rosendahl *et al.* (1936), who state that "Often the leaves produced in the late summer, which usually persist throughout the winter, are of quite different size and shape from those produced during active growth in the spring." Failure to describe these seasonal variations in leaves is apparently due to the practice of limiting observation largely or entirely to plants in the flowering condition. As a result, the growth regimes of winter-green and most other herbaceous species, as well, are imperfectly known.

ECOLOGY OF THE WINTER FLORA

Daily, seasonal, and annual regimes of the major weather elements, as measured by official agencies and as referred to in most ecological reports, bear slight resemblance to actual environmental conditions surrounding plants in the lowest layer of air (Wolfe, 1944). Especially is this true of above-ground parts of plants during winter. An intensive study of environmental conditions was not within the scope of this investigation, but attention is here called to some general conditions and certain problems associated with the ecology of the winter-greens.

Solar radiation is a major weather control, and in local situations is especially important in relation to air and soil temperatures, and consequently to the rates of processes in plants. On the forest floor insolation during the winter months is never less than five times greater than that in mid-July (Wolfe, *et al.*, 1949). A conspicuous increase in light intensity during October and November, and rapid decrease during April and May, result respectively from disappearance of the canopy and its closure. Light intensities during the winter months are probably more than adequate for photosynthesis.

Because of this insolation, temperatures of plants themselves may be higher during the daytime than air temperatures a few feet above them. Likewise, minimum temperatures of plants are ordinarily lower than those of this air during the night or other times when radiation exceeds insolation. Since official Weather Bureau air temperatures are not usually those of the air surrounding plants (Wolfe, *et al.*, 1949), the range of temperature to which the above-ground parts of plants are subjected in winter, as a result of fluctuating air temperatures and insolation and radiation, can only be guessed until actual measurements of the temperatures of the plants themselves are made.

Temperatures to which winter leaves of plants are exposed range from well below freezing to considerably above freezing. This range is greater in fully exposed habitats, such as cliff faces and denuded roadside banks, than in forest communities where plants are commonly surrounded by leaf litter. Even in forest conditions the leaves may be frozen solid at times during daylight hours. Those of *Dianthus armeria* and *Epilobium coloratum*, both pioneer species, have been found a number of times frozen so solidly that a slight touch was sufficient to break off a leaf. That temperatures are often low enough to freeze above-ground parts, in nearly any natural habitat in Ohio, and yet not result in death of these organs, has been observed many times in the field.

Lowest minimum temperatures to which these plants are exposed, and highest maximums, occur where insolation in daytime and radiation at night are greatest. In forest habitats, leaf litter conditions modify minimum temperatures upwards. In fully exposed situations, minimums may conceivably be less than 0°F on certain

winter nights. Exposure to the most extreme minimums rarely occurs in any habitat of an area, since these extremes almost always follow snowfall (Dole, 1927, and Beatley, 1953). Under snow, temperatures remain essentially uniform day and night. In the absence of snow, however, temperatures of exposed parts of plants may sometimes rise well above freezing in the daytime even if air temperature is below 32°F. What maximum temperatures plant tissues may attain is not known, but during daylight hours they must often be considerably above 32°F, as evidenced by widespread thawing of adjacent substrates and melt-water on cliff faces.

Underground parts of forest plants are rarely, if ever, exposed to sub-freezing temperatures since the soil beneath even a moderately deep leaf litter rarely freezes (Wolfe, 1949). Where leaf litter is scanty or absent, soils may be frozen solid during certain periods. Since the temperatures of roots and other underground organs are essentially the same as the surrounding soil, the below-ground tissues are either never frozen or frozen only during certain periods. While upper soil temperatures are lower in winter than in other seasons, and while water absorption may be reduced under these conditions, it probably does not cease as long as the soil is unfrozen. That availability of water may be a factor in the distribution of winter-greens is indicated by the nature of vegetation along stream banks and in other wet or moist habitats. Here plants are most abundant in the winter, best developed, and the brightest green. Water relations in winter-green herbs, especially absorption and transpiration, seem worthy of study out-of-doors, or at least under simulated field conditions.

A discussion of the physiology of winter-greens is beyond the scope of this paper, but two processes which appear to have possible ecological significance should be mentioned, *viz.*, photosynthesis and growth. Although winter photosynthesis is not known to have been measured in native herbaceous plants, there is no reason to assume that it does not occur since light intensities are not limiting, daytime temperatures some of the time (perhaps much of the time) are not unfavorable, and water absorption can occur in forest plants the winter through and in others at least during certain periods. If photosynthesis occurs in winter, even intermittently, a new field of problems becomes apparent, including the importance of this process in winter to the survival of plants in which it occurs, and its significance in certain problems of plant distribution.

It is certain from both field inspection and observations of plants transplanted to the Botanical Garden, that growth of leaves occurs in the Ohio region during winter both under snow cover and exposed. The so-called growing season appears from these observations to be in reality a period of accelerated growth, while the winter season, at least for some species, is one of merely decelerated growth. Actual measurements of rates of winter growth, its periodicity, conditions under which it occurs, its physiological significance, and its relation to plant distribution are problems which have been investigated as yet in only isolated instances.

That a period of low temperatures is often requisite to the breaking of dormancy[2] of many native perennials, and certain biennials as well, has been clearly indicated by attempts to force flowering in greenhouse conditions during this study. Similar observations of native perennial species were made by Rosendahl (1914) a number of years ago. Examples of species for which a cold period, or its equivalent, was found necessary in the present study are *Lobelia cardinalis*, *Dianthus armeria*, *Hieracium* spp., and most species of *Aster and Solidago*. Measurements of degree and duration of low temperatures requisite to the breaking of dormancy in native herbaceous plants have not been made. Also, alternating

[2]The dormant condition, as used in this paper, refers to the winter vegetative condition. Breaking of dormancy refers to elongation of the stems of tufts and rosettes, and to initiation of flower primordia in plants with elongated internodes in the winter condition.

periods of low and relatively higher temperatures, which may be factors in breaking of dormancy, are open to further investigation. The minimum duration and degree of low temperatures, and alternating "cold" and "warm" periods necessary for each species can be expected to differ widely. Whatever these requisites are, they apparently are satisfactorily met within the diverse microclimates in which native species of the Ohio region pass the winter.

The full extent to which effects of low temperatures on the processes related to dormancy are controlling factors in plant macrodistribution can only be surmised. Local distribution may also be related to the particular winter conditions necessary to fulfill very specific requirements of some species during the dormant period. These winter conditions may prevail only in certain microhabitats. The local distribution of some species, regardless of their possible ecological amplitude at other seasons, may conceivably be limited by the environmental complexes which characterize winter microclimates. The study of these conditions, using winter-green species, may prove a fruitful approach to local distribution problems.

The extent to which all of the species enumerated here are winter-green in all habitats in which they may grow is unknown. Most, especially the native forest species, are believed to have winter leaves in most, if not all, of the habitats in which the species occur. A single exception is known: *Viola papilionacea* is winter-green in certain valleys of Fairfield and Hocking Counties, but does not appear to be so in swamp forests of the Columbus area. Whether such variation in behavior is due to genotypic or environmental differences, or both, is not known; it can only be said, on the basis of present information, that within each of the species there must be at least some biotypes in which the potentiality of winter-greenness is expressed in at least some environments. It is suggested that, in general, species of relatively broad ecological amplitudes are those most likely to be demonstrated not to be winter-green in all habitats in which they occur.

Ecological classification of the winter-green species. The herbaceous winter-greens may be classified in a general way on the basis of their association with the major vegetation types. The numbers of species and abundance of individuals which make up the winter ground cover societies vary conspicuously among the vegetation types. In the Oak-Chestnut association, species are numerous but individuals usually occur as scattered specimens and are nowhere abundant. This is generally true also of Beech-Sugar Maple forests, where number of species and individuals is somewhat correlated with degree of disturbance. Of the forest communities, number of species is greatest and individuals are most abundant in swamp forests. Greatest paucity of species occurs in Hemlock and Hemlock-Beech communities, where but one species, *Mitchella repens*, together with Christmas Fern (*Polystichum acrostichoides*), constitutes the ground layer society the year around. In general, it is in the pioneer habitats such as old fields and their developmental stages, and unforested flood plains and stream banks, in which the greatest diversity of the winter flora occurs; here also individuals are most abundant. In these pioneer sites, the ground may be locally nearly carpeted with green throughout the winter season.

In the ecological classification which follows, those which are referred to as "common" generally occur in most communities with which they are associated, though they may not necessarily be abundant. Species considered as "frequent to infrequent" are those which may occasionally occur in these vegetation types, or may be almost common under certain conditions. Species introduced into Ohio are indicated by (I).

Swamp Forest communities, including such developmental societies as are found in marshes, swales, wet old fields and sandbars, as well as the strictly arboreal communities of Sycamore-Cottonwood-Willow, Elm-Ash-Soft Maple, Mixed Swamp Forest, and their related types.

Common to abundant:

Elymus virginicus
Stellaria media (I)
Claytonia virginica
Ranunculus abortivus
Barbarea vulgaris (I)
Geum canadense
Agrimonia parviflora
Viola striata
Chaerophyllum procumbens
Osmorhiza claytoni
O. longistylis
Lysimachia nummularia (I)
L. ciliata
Glechoma hederacea
Galium aparine
G. triflorum
Valerianella intermedia
Aster cordifolius
A. prenanthoides
A. lateriflorus
Senecio obovatus
S. aureus

Frequent to infrequent:

Cinna arundinacea
Hystrix patula
Panicum spp.
Carex plantaginea
C. gracilescens
Juncus effusus
Allium vineale (I)
Stellaria longifolia
Cerastium vulgatum (I)
C. nutans
C. viscosum (I)
Ranunculus sceleratus
R. recurvatus
R. septentrionalis
Isopyrum biternatum
Rorippa islandica
Cardamine bulbosa
C. douglassii
C. pensylvanica
Geum virginianum
G. vernum
Agrimonia gryposepala
Hypericum punctatum
H. mutilum
Viola papilionacea
Epilobium coloratum
Sanicula gregaria
Zizia aurea
Cryptotaenia canadensis
Thaspium trifoliatum
T. barbinode
Heraceum maximum
Polemonium reptans
Vicia caroliniana
Hydrophyllum canadense
Phacelia purshii
Prunella vulgaris (I)
Leonurus cardiaca (I)
Lamium purpureum (I)
L. amplexicaule (I)
Blephilia hirsuta
Lobelia cardinalis
L. siphilitica
Solidago flexicaulis
S. patula
S. rugosa
Aster puniceus
A. tradescanti
Erigeron pulchellus
E. philadelphicus
Polymnia canadensis
Rudbeckia laciniata
Lactuca canadensis

Rare:

Saxifraga pensylvanica
Viola conspersa
Samolus floribundus
Phlox stolonifera

Beech-Sugar Maple association and its borders.

Common:

Silene virginica
Claytonia virginica
Hepatica acutiloba
H. americana
Heuchera americana
Mitella diphylla
Osmorhiza claytoni
O. longistylis
Phlox divaricata
Galium aparine
G. triflorum
Mitchella repens
Solidago caesia
Aster cordifolius

Frequent to infrequent, or common locally:

Carex spp.
Ranunculus abortivus
R. recurvatus
Anemone virginiana
Isopyrum biternatum
Stellaria longifolia
Cardamine douglassii
Tiarella cordifolia
Geum canadense
G. virginianum
Viola papilionacea
V. rostrata
Cryptotaenia canadensis
Obolaria virginica
Polemonium reptans
Hydrophyllum canadense
H. appendiculatum
Blephilia hirsuta
Solidago flexicaulis
Aster macrophyllus
Erigeron pulchellus
Senecio obovatus

Mixed Mesophytic or Hemlock-Hardwood associations or both.

Common:

Mitchella repens *Aster divaricatus* *A. cordifolius*

Frequent to rare, or common locally:

Goodyera pubescens
Aplectrum hyemale
Tiarella cordifolia
Heuchera americana
Chrysosplenium americanum
Viola blanda
Coptis groenlandica
Pyrola rotundifolia
P. elliptica
P. secunda
Galium aparine

Oak associations, including Oak-Chestnut, Oak-Hickory, and Oak-Pine, and their borders.

Common:

Panicum lanuginosum
Saxifraga virginiensis
Heuchera americana
Fragaria virginiana
Potentilla simplex
Epigaea repens
Gaultheria procumbens
Mitchella repens
Solidago caesia
Aster cordifolius
Antennaria plantaginifolia

Frequent to infrequent:

Hystrix patula
Panicum spp.
Carex spp.
Luzula campestris
L. acuminata
Chamaelirium luteum
Goodyera pubescens
Silene virginica
S. pensylvanica
Hepatica acutiloba
H. americana
Anemone virginiana
Sedum ternatum
Vicia caroliniana
Viola triloba
Chimaphila umbellata
C. maculata
Sabatia angularis
Obolaria virginica
Phlox divaricata
Arabis laevigata
Salvia lyrata
Blephilia ciliata
Veronica officinalis
Galium pilosum
Houstonia longifolia
Lobelia inflata
L. spicata
Solidago nemoralis
S. erecta
Aster macrophyllus
Gnaphalium spp.
Senecio oboatus
Hieracium venosum
H. paniculatum
H. gronovii

Crevice, Ledge, Cliff Face, or Cliff Top communities.

Silene rotundifolia
Hepatica americana
H. acutiloba
Aquilegia canadensis
Corydalis flavula
Arabis patens
A. laevigata
Sedum ternatum
Saxifraga virginiensis
Lechea racemulosa
Epigaea repens
Houstonia longifolia
Aster laevis

Old Fields and developmental phases, including lawns, pastures, roadsides and cultivated grounds.

Common to abundant:

Bromus spp. (I)
Danthonia spicata
Andropogon virginicus
Allium vineale (I)
Rumex spp. (I)
Stellaria media (I)
Cerastium vulgatum (I)
Dianthus armeria (I)
Ranunculus abortivus
Lepidium virginicum
Capsella bursa-pastoris (I)
Barbarea vulgaris (I)
Fragaria virginiana
Potentilla norvegica
P. simplex
Trifolium spp. (I)
Medicago lupulina (I)
Oenothera biennis
Daucus carota (I)
Prunella vulgaris (I)
Leonurus cardiaca (I)
Verbascum thapsus (I)
V. blatteria (I)
Veronica officinalis
V. serpyllifolia
V. arvensis (I)
Plantago major (I)
P. rugelii
P. lanceolata (I)
Dipsacus sylvestris (I)
Solidago nemoralis
S. juncea
Aster pilosus
Erigeron annuus
E. strigosus
Antennaria plantaginifolia
Gnaphalium obtusifolium
Achillea millefolium
Chrysanthemum leucanthemum (I)
Cirsium vulgare
Taraxacum officinale (I)
Lactuca spp.

Frequent to infrequent, or common only locally:

Arenaria serpyllifolia (I)
Cerastium nutans
Agrostemma githago (I)
Lychnis alba (I)
Silene antirrhina
Draba verna (I)
Brassica spp. (I)
Sisymbrium spp. (I)
Arabidopsis thaliana (I)
Potentilla recta (I)
Vicia spp. (except *V. caroliniana*) (I)
Viola sagittata
Gaura biennis
Sabatia angularis
Lithospermum arvense (I)
Blephilia ciliata
Plantago aristata
P. virginica
Houstonia caerulea
H. longifolia
H. canadensis
Lobelia spicata
L. inflata
Solidago rugosa
S. rigida
Aster laevis
Erigeron philadelphicus
Gnaphalium purpureum
Rudbeckia hirta
R. triloba
R. laciniata
Hieracium gronovii

Prairie communities.

Salvia lyrata	*Solidago nemoralis*
Blephilia ciliata	*S. rigida*
Castilleja coccinea	*Aster pilosus*
Houstonia longifolia	*Rudbeckia hirta*
H. canadensis	*R. triloba*
Lobelia spicata	*R. speciosa*

KEY TO THE WINTER-GREEN HERBACEOUS FLOWERING PLANTS OF CENTRAL AND SOUTHERN OHIO[3]

1. Leaves longitudinally veined 2
1. Leaves not longitudinally veined 12
   2. Leaves with split or closed sheaths, blades grass-like, many times longer than broad (except in *Panicum* spp.), many-veined 3
   2. Leaves without sheaths, blades usually not grass-like 5
3. Blades ending in a gland-like tip, leaf sheaths closed; more or less webbed-hairy . . *Luzula* spp.
3. Blades not ending in a gland-like tip, or if so, leaf sheaths split or open 4
   4. Leaves with sheaths split on the side opposite the blade, 2-ranked ..... Gramineae
   4. Leaves with closed sheaths, 3-ranked ..... Cyperaceae
5. Leaves hollow, circular in cross-section, sometimes grooved on upper side, with a strong onion odor, up to 40 cm. long ..... *Allium vineale*
5. Leaves flat, not hollow 6
   6. Blades grass-like, 2–6 mm. broad, 3-veined, narrowed to short, slender, margined petioles ..... *Plantago aristata*
   6. Blades not grass-like 7
7. Leaves solitary, plaited, erect ..... *Aplectrum hyemale*
7. Leaves not solitary, several to many in a more or less flat rosette 8
   8. Leaves dark green with 5–7 white main veins and many fine white reticulating veins ..... *Goodyera pubescens*
   8. Leaves not white-veined 9
9. Leaves villous-pubescent; obovate, oblong or linear; prairies ..... *Castilleja coccinea*
9. Leaves not villous, but glabrous or pubescent 10
   10. Blades narrowly oblong to lanceolate, less than 2.5 cm. broad, with tufts of long matted brownish or whitish hairs at the bases of the petioles .... *Plantago lanceolata*
   10. Leaves spatulate, mostly more than 2.5 cm. broad 11
11. Blades bright or pale green, tapering into margined petioles shorter than the blades, entire, smooth and glabrous, more than 7-veined (usually many-veined); forest species, rare except locally ..... *Chamaelirium luteum*
11. Blades dark green, abruptly narrowed into stout, unmargined, channelled petioles about the same length as or shorter than the blades, entire, undulate, or shallowly dentate, glabrous or sparingly pubescent, 5 7-veined; common weed of lawns, roadsides and waste grounds ..... *Plantago major*
    P. rugelii
   12. Leaves very finely 2-3-pinnately dissected, the ultimate segments (or lobes) linear or narrowly linear-lanceolate, rarely more than 1 mm. broad, the leaves with a feathery appearance; plants with a strong odor; weeds of roadsides, fields, and waste grounds 13
   12. Leaves not finely 2–3-pinnately dissected as above 15
13. Blades with 12 30 pairs of primary divisions; ultimate segments linear-oblong, less than 1 mm. broad, blades 2 5 cm. broad; horizontal rhizome ..... *Achillea millefolium*

[3]Based upon winter field characters.

13. Blades with fewer than 10 pairs of primary divisions 14
    14. Plants with a long, stout, fleshy taproot, ultimate leaf segments or lobes about 1 mm. broad, leaves more than 5 cm. long, petioles long and slender, leaves tufted ..... *Daucus carota*
    14. Plants not with a long, fleshy taproot, ultimate leaf segments linear or filiform, usually less than 0.5 mm. broad, leaves sessile or nearly so, 2–5 cm. long, alternate on short, simple or branched stems ..... *Anthemis cotula*
15. Leaves compound, or so deeply divided as to appear compound, the segments distinct or nearly so 16
15. Leaves simple 54
    16. Most of the leaves ternately compound, ternately decompound, or simple but 3-divided (*i.e.*, with 3 distinct segments) 17
    16. Leaves not ternately compound, ternately decompound, or 3-divided 33
17. Blades biternate 18
17. Blades once-ternate 23
    18. Ultimate leaflets pinnatifid with oblong, obtuse lobes 1–7 mm. long, 1–3 mm. broad, sheath with a scarious, villous margin ..... *Chaerophyllum procumbens*
    18. Ultimate leaflets not pinnatifid 19
19. Plants, especially the roots, with an anise or licorice odor; leaflets coarsely serrate, dentate or incised, sparingly or densely pubescent throughout ..... *Osmorhiza* spp.
19. Plants not with an anise or licorice odor 20
    20. Ultimate leaflets ovate, acute at the apex, sharply serrate, and if lobed, the lobes acute 21
    20. Ultimate leaflets wedge-shaped, obtuse at the apex and obtusely lobed, not serrate 22
21. Leaflets sharply and closely serrate ..... *Zizia aurea*
21. Leaflets coarsely serrate or incised ..... *Thaspium barbinode*
    22. Leaflets mostly longer than 1.5 cm., the lobes not mucronate, veins usually inconspicuous above, glabrous to softly pubescent ..... *Aquilegia canadensis*
    22. Leaflets mostly less than 1.5 cm. long, lobes minutely mucronate, veins prominent above, smooth and entirely glabrous ..... *Isopyrum biternatum*
23. Leaves alternate on stems with elongated internodes, leaflets denticulate or serrulate ... 30
23. Leaves tufted, leaflets serrate, dentate, crenate, or incised, always conspicuously toothed .. 24
    24. Petioles without definite stipules, although usually dilated into membranous-margined bases and sheathing 25
    24. Petioles with definite stipules 29
25. Blades mostly broader than long, leaflets variously cleft into sharply toothed lobes, short-stalked or sessile; chiefly in Beech-Sugar Maple or Oak-Chestnut woods ..... *Anemone virginiana*
25. Blades not mostly broader than long 26
    26. Petioles densely long-pubescent, hollow, strongly dilated at the base; terminal leaflet broadly ovate or orbicular in outline, commonly 3-lobed, 6–12 cm. broad, laterals smaller, broadly ovate, 2–3-lobed, all bluntly or acutely toothed, stalked; swamp forests and other moist grounds ..... *Heracleum maximum*
    26. Petioles not densely long-pubescent, hollow, or strongly dilated at the base, or if so, not otherwise as above 27
27. Leaflets closely, sharply, and doubly serrate, the terminal one abruptly narrowed into a margined, toothed stalk or less commonly cuneate at the base, leaflets thin, glabrous ..... *Cryptotaenia canadensis*
27. Leaflets not as above 28
    28. Leaflets finely, regularly and closely crenate-dentate, ovate or ovate-lanceolate, cordate at the base and the lateral usually strongly oblique, sessile or short-stalked, the terminal long-stalked, smooth and glabrous, thickish ..... *Thaspium trifoliatum*

28. Leaflets coarsely serrate, cleft into 2–3 broad lobes which in turn are usually lobed or incised, sparingly pubescent or glabrate, thin.... *Ranunculus septentrionalis*

29. Stipules membranous, white, ovate-oblong, about 0.5 cm. broad and 1 cm. long, entire, sparingly hirsute or glabrate; leaflets coarsely serrate..... *Fragaria virginiana*

29. Stipules greenish, lanceolate-oblong, 1 mm. or less broad, less than 1 cm. long, dentate, hirsute; blades coarsely incised-serrate..... *Potentilla norvegica*

30. 6–12 veins on either side of the midvein of each leaflet, stipules ovate or lanceolate, dentate or entire, blades pinnately 3-foliate..... *Medicago lupulina*

30. 20–30 veins on either side of the midvein of each leaflet, stipules not dentate, leaflets all from the same point..... 31

31. Leaflets finely denticulate; stipules ovate, leaves more or less pubescent and usually with a pale spot on the upper side..... *Trifolium pratense*

31. Leaflets serrulate with sharp-pointed, spine-like teeth; stipules ovate-lanceolate, blades glabrous, usually not with a pale spot on the upper side..... 32

32. Stems creeping and rooting at the nodes, stipules mostly less than 1 cm. long..... *Trifolium repens*

32. Stems ascending or decumbent, stipules mostly 1–2 cm. long... *Trifolium hybridum*

33. Blades digitately 5–7-foliate..... 34

33. Blades not digitately 5–7-foliate..... 36

34. Stipules adnate to bases of the petioles, tips free; blades 5–7-foliate, more or less villous-pubescent, especially below..... 35

34. Petioles expanded at the base and sheathing, but not with stipules; blades 5-foliate, the leaflets thin, distinct or commonly the lateral slightly united at the base, all about the same size, wedge-shaped or obovate, 2–6 cm. long, sharply and mostly doubly serrate with bristle-tipped teeth, glabrous.... *Sanicula gregaria*

35. Leaflets (exclusive of stalks) mostly 1–3 cm. long, obovate or oval, coarsely serrate, commonly glossy, dark green above, firm and thickish, usually ascending..... *Potentilla simplex*

35. Leaflets (exclusive of stalks) mostly 3–6 cm. long, oblanceolate or oblong-lanceolate, not glossy, bright green, thin and flaccid, incised-dentate with divergent teeth, spreading on the ground..... *Potentilla recta*

36. Blades pinnately decompound..... 37

36. Blades once-pinnately compound or divided..... 41

37. Petioles dilated into membranous-margined bases..... 38

37. Petioles not dilated as above; blades rather finely dissected into linear, oblong or wedge-shaped segments, acutely or obtusely toothed or lobed, pale green, glabrous, slender-petioled..... *Corydalis flavula*

38. Plants, especially the roots, with an anise or licorice odor; leaflets coarsely serrate, dentate or incised, sparingly or densely pubescent throughout..... *Osmorhiza* spp.

38. Plants not with an anise or licorice odor..... 39

39. Ultimate leaflets pinnatifid with oblong, obtuse lobes 1–3 mm. broad, sheath with a scarious, villous margin..... *Chaerophyllum procumbens*

39. Ultimate leaflets broad, not pinnatifid..... 40

40. Leaflets sharply and closely serrate..... *Zizia aurea*

40. Leaflets coarsely serrate or incised..... *Thaspium barbinode*

41. Leaves even-pinnate, alternate on trailing, branched, weak stems, rachises terminating in slender tendrils, leaflets small..... 42

41. Leaves odd-pinnate, *i.e.*, with a terminal leaflet..... 44

42. Tendrils forked; fields, roadsides and waste places..... 43

42. Tendrils mostly unforked (simple); woodland borders..... *Vicia caroliniana*

43. Leaves and stem villous-pubescent..... *Vicia villosa*

43. Leaves glabrous or glabrate..... *Vicia sativa*
V. angustifolia

44. Plants strictly aquatic, usually in small streams or at outlets of springs, many plants occurring together and covering the water surface; leaves not in rosettes (except in late winter), 3–9 leaflets, terminal one larger than the lateral and nearly orbicular ..... *Nasturtium officinale*
44. Plants terrestrial, or if growing in water, then in distinct, usually symmetrical rosettes 45
45. Petioles with distinct stipules adnate to the base, the tips free; principal leaflets not varying greatly in size, deeply serrate, with small, interposed leaf segments 46
45. Petioles without stipules, or if present, not otherwise as above 47
46. Principal leaflets 11–17, close together and crowded ..... *Agrimonia parviflora*
46. Principal leaflets mostly 5 or 7, not crowded or close together ..... *Agrimonia gryposepala*
47. Terminal leaflet sharply 3- or 5-lobed 48
47. Terminal leaflet not 3–5-lobed, or (in *Geum* spp.) the lobes rounded and usually shallow .. 49
48. Leaves large, 10–20 cm. long, 6–14 cm. broad, 3–7-divided, the lowest lateral leaflets the longest, 3–7 cm. long, all sharply and coarsely toothed, acutely lobed or incised ..... *Rudbeckia laciniata*
48. Leaves 2–5 cm. long, 1–2 cm. broad, 5–11-divided, the lowest lateral leaflets the smallest, less than 0.5 cm. long, all entire or sparingly toothed, obtuse or acute at the apex ..... *Phacelia purshii*
49. Roots, petioles and veins with bright orange or yellow sap; leaflets mostly 7, obovate or ovate, 2–3.5 cm. long, 1–2.5 cm. broad, crenate-lobed, the lobes or teeth all very obtuse, petioles dilated at the base and clasping ..... *Chelidonium majus*
49. Plants not with bright orange or yellow sap, or if so, not otherwise as above 50
50. Terminal leaflet about the same size as the laterals; leaflets 3–7 pairs and the terminal one, elliptic or ovate, 0.5–2 cm. long, entire, glabrous, sessile ..... *Polemonium reptans*
50. Terminal leaflet conspicuously larger than the lateral 51
51. Leaves more or less softly pubescent all over; 3–7 principal leaflets, with or without small interposed segments, ovate or obovate, more or less shallow round-lobed or incised, dentate or crenate ..... *Geum* spp.
51. Leaves glabrous 52
52. Terminal leaflet orbicular, 2–5 cm. broad, cordate or rounded at the base, rosettes glossy dark green 53
52. Terminal leaflets obovate, less than 2 cm. broad, narrowed at the base, rosettes bright green and not shining; 2–8 pairs of lateral leaflets .... *Cardamine pensylvanica*
53. 1–4 pairs of lateral leaflets ..... *Barbarea vulgaris*
53. 4–8 pairs of lateral leaflets ..... *Barbarea verna*
54. Leaves opposite, alternate, or whorled on a simple or branched stem with distinct internodes (in *Houstonia* spp. internodes short but usually leaves borne on minutely branched stems) 55
54. Leaves in a flat rosette or tufted, stems always simple and with greatly reduced internodes 95
55. All or some of the leaves verticillate 56
55. Leaves all opposite or alternate 62
56. Leaves verticillate in 3's, thick and succulent; light green, 0.5–2 cm. long, usually crowded at the end of the stem ..... *Sedum ternatum*
56. Leaves not verticillate in 3's, or if so, not thick and succulent 57
57. Leaves all verticillate on weak, 4-angled stems in 4's, 6's, or 8's, more than one whorl on each stem 58
57. Stems not 4-angled, leaves not all verticillate, or if so, stems not as above 60
58. Leaves rather densely hirsute or pubescent, punctate, all in 4's; oval to ovate, eastern Ohio ..... *Galium pilosum*
58. Leaves glabrous or glabrate except for the margins or midveins, in whorls of 6 or 8, or the older ones commonly in 4's 59

59. Biennial, plants very fragile, cotyledons persistent; leaves 0.5–3 cm. long, usually at least some of them in 6's or 8's, mucronate, stems sometimes hairy at the nodes..... ..... *Galium aparine*

59. Perennial, usually many branches arising from the base, stems slender but not extremely fragile; leaves 0.5–1.5 cm. long, usually most of them in 6's, strongly mucronate..... ..... *Galium triflorum*

60. Leaves mostly opposite with some verticillate on the same stem, less than 1 cm. long, not coriaceous, entire..... *Lechea racemulosa*

60. Leaves verticillate or scattered on the suberect stem, 1–8 cm. long, coriaceous, serrate 61

61. Leaves mottled with white along the veins, 2.5–8 cm. long, ovate or ovate-lanceolate.... ..... *Chimaphila maculata*

61. Leaves not mottled, dark green and shining, 1–5 cm. long, spatulate or cuneate-oblanceolate..... *Chimaphila umbellata*

62. Leaves alternate..... 63

62. Leaves opposite..... 66

63. Blades sharply and rather shallowly serrate; lanceolate, prominently 3-veined, smooth and glabrous except for the rough margins and ciliate petioles, acute or subacuminate at the apex, gradually tapering into short, margined petioles, internodes only slightly elongated; swamp forests or moist pioneer sites..... *Solidago gigantea*

63. Blades entire..... 64

64. Leaves thin; bright green, oblong to oblanceolate, 1–6 cm. long; marshy places... ..... *Myosotis scorpioides*

64. Leaves thick and more or less coriaceous; stem somewhat woody..... 65

65. Leaves clustered (mostly in 3's) at the ends of creeping branches, dark green, shining above, pale beneath, blades oval, oblong, or obovate..... *Gaultheria procumbens*

65. Leaves not appearing clustered, bright or dark green above, not pale beneath or shining above, dull, blades oval or nearly orbicular, often forming large patches..... *Epigaea repens*

66. Stems strongly and distinctly 4-angled, not twisted..... 67

66. Stems not 4-angled, or (in *Lysimachia*) obscurely so and slightly twisted..... 71

67. Blades 3–5 palmately lobed, 2–8 cm. long and nearly as broad; blades very veiny, lobes acute or acuminate, incised or dentate..... *Leonurus cardiaca*

67. Blades not lobed, mostly 1–3.5 cm. long..... 68

68. Blades pinnately veined, serrate; plants rather densely villous throughout, branches creeping, decumbent, or ascending..... *Blephilia hirsuta* in swamp forests or other moist sites
B. ciliata in dry pioneer sites or Oak forests

68. Blades palmately veined or nearly so (3–5 main veins originating at or near the base of blade), usually deeply crenate..... 69

69. Plants with a pungent odor, stems creeping with many small ascending branches; blades orbicular or reniform..... *Glechoma hederacea*

69. Plants not with a pungent odor, stems merely decumbent (although sometimes rooting at the lower nodes) and branched mostly at the base..... 70

70. Lower leaf blades orbicular or broadly ovate, upper ones ovate, all petioled.... ..... *Lamium purpureum*

70. All leaf blades orbicular or nearly so, the lower petioled, the upper sessile and more or less clasping..... *Lamium amplexicaule*

71. Leaves copiously black-dotted, especially at the margins; 4-ranked, glabrous, oblong or ovate-lanceolate, obtuse, sessile or short-petioled, mostly 1–2 cm. long..... ..... *Hypericum punctatum*

71. Leaves not black-dotted..... 72

72. Leaves small, mostly 0.5–2 cm. long, crowded, thickish, entire, internodes very short, stem minutely more or less highly branched, stout and rigid..... 73

72. Plants not as above..... 75

73. Leaves all less than 1 cm. long, 1–3 mm. broad, spatulate, oblanceolate or obovate, sparingly short-pubescent above and sometimes appearing ciliolate but the hairs not in definite rows, petioles usually as long as or longer than the blades; highly branched forms forming polsters ..... *Houstonia caerulea*

73. Most of the leaves more than 1 cm. long, sparingly short-pubescent above or glabrous, ciliate or not, petioles usually not as long as the blades 74

74. Leaves ciliate, *i.e.*, the hairs in definite rows, blades elliptic to suborbicular, petioles usually shorter than the blades but sometimes as long or longer ..... *Houstonia canadensis*

74. Leaves not ciliate, *i.e.*, with the hairs in definite rows, although frequently appearing so, commonly glabrous throughout, petioles rarely as long as the blades and usually much shorter ..... *Houstonia longifolia*

75. Plants minute, leaves less than 5 mm. long, thin, close together but not crowded, slightly downy-pubescent, stems swollen at the nodes, simple or branched .... *Arenaria serpyllifolia*

75. Leaves longer than 5 mm 76

76. Plants semi-aquatic, in well-lighted seepage areas; blades bright green, broadly ovate, orbicular or almost reniform, crenate ..... *Chrysosplenium americanum*

76. Plants terrestrial 77

77. Blades deeply pinnatifid, the lobes acute or acuminate at the apex, dentate or incised-dentate, leaves 3–25 cm. long, petioles commonly purple with a pair of dilated, foliaceous appendages at the base ..... *Polymnia canadensis*

77. Leaves not pinnatifid 78

78. Leaves entire or undulate 79

78. Leaves serrate, crenate, dentate, or obscurely toothed 91

79. Blades broadly obovate to wedge-shaped, sessile, clasping, and crowded on the simple, erect stem, the stem 6–10 cm. high, leaves entire, dark green, thickish or coriaceous, 0.8–2.5 cm. long ..... *Obolaria virginica*

79. Leaves not as above 80

80. Blades orbicular or broadly ovate, mostly less than 2 cm. long, with short, unmargined petioles, glabrous throughout 81

80. Blades not orbicular or broadly ovate, or if so, not otherwise as above 82

81. Leaves dark green, some or all of them with a whitish midvein; plants characteristic of Hemlock, Hemlock-Beech, and Oak-Chestnut forests ..... *Mitchella repens*

81. Leaves bright green, not with a whitish midvein, minutely glandular-punctate, stem angled; common in swamp forests ..... *Lysimachia nummularia*

82. Blades linear or linear-lanceolate, glabrous throughout 83

82. Blades not linear or linear-lanceolate, or if so, pubescent 84

83. Leaves 2, 5–15 cm. long ..... *Claytonia virginica*

83. Leaves more than 2, 0.5–2.5 cm. long ..... *Stellaria longifolia*

84. Blades ovate or elliptic, mostly more than 2 cm. long, firm and somewhat coriaceous, usually dark green 85

84. Blades obovate, oblanceolate, or if ovate, then less than 2 cm. long, not at all coriaceous, usually bright green 87

85. Stems prostrate and trailing, plants forming a dense carpet over the ground, stems usually much longer than 15 cm.; leaves glabrous, short-petioled, glossy .... *Vinca minor*

85. Stems erect or ascending, or rarely decumbent, not trailing, usually less than 15 cm. long, plants occurring singly; margins of blades rough with short, stiff hairs 86

86. Leaves sessile, 1-veined ..... *Phlox divaricata*

86. Blades narrowed into short, margined petioles, lateral veins conspicuous and uniting near the margin ..... *Phlox paniculata*

87. Plants glabrous except for a line of hairs along the petioles and stem; blades ovate, frequently cordate at the base ..... *Stellaria media*

87. Plants more or less pubescent throughout 88

88. Leaves obovate, varying from 2–8 cm. long on the same branch, 1–3 cm. broad, softly pubescent above, smooth and satin-like beneath; Jackson, Hocking, Fairfield, and Athens Counties ..... *Phlox stolonifera*
88. Leaves oblanceolate, spatulate or spatulate-oblong, the largest not over 4 cm. long and rarely more than 1 cm. broad 89

89. Leaves mostly 2–4 cm. long, oblanceolate or spatulate, sparingly hirsute above, glabrous or nearly so beneath, thin; petioles margined, rather slender, usually as long as or longer than the blades ..... *Cerastium nutans*
89. Leaves mostly 1–2 cm. long, obovate or spatulate, or the blades oblong, hirsute above and below, thick 90
90. Leaves mostly 1–2 cm. long and 0.5–1 cm. broad on short stems; chiefly southern and eastern Ohio ..... *Cerastium viscosum*
90. Leaves mostly less than 1 cm. long and 0.5 cm. broad, on ascending or decumbent stems with elongated internodes; common weed of moist sites .... *Cerastium vulgatum*

91. Blades finely and regularly serrate, 1–3 cm. long, softly pubescent throughout .... *Veronica officinalis*
91. Blades not finely serrate as above 92
92. Blades denticulate; oblong, thick and fleshy, 0.5–2 cm. long, glabrous .... *Veronica peregrina*
92. Blades crenate, crenulate, dentate (sometimes entire in *V. serpyllifolia*) 93

93. Blades crenulate or rarely entire, mostly 0.5–1 cm. long, glabrous or puberulent .... *Veronica serpyllifolia*
93. Blades pubescent; crenate, dentate, or crenulate 94
94. Blades crenate to dentate, 0.5–2 cm. long, ovate or oval, more or less pubescent; not common ..... *Veronica persica*
94. Blades crenate or crenulate, broadly ovate to oval, 5–12 mm. long; common weed ..... *Veronica arvensis*

95. Leaves with milky sap 96
95. Leaves not with milky sap 104
96. Teeth minutely but conspicuously white callose-tipped, the margins more or less strongly crisped; leaves less than 8 cm. long, in flat rosettes 97
96. Margins not both crisped and with callose-tipped teeth 100

97. Plants of swamp forests, stream banks and open, marshy places 98
97. Plants of dry woods or fields, or waste grounds 99
98. Leaves acute at the apex, smooth and glabrous throughout or sparingly short-pubescent; along stream banks or sometimes in open, marshy places .... *Lobelia cardinalis*
98. Leaves obtuse at the apex or sometimes acutish, short-pubescent or glabrate above, glabrous beneath; swamp forest species, less frequently in open wet places ..... *Lobelia siphilitica*

99. Leaves loosely hirsute above, and especially on the veins beneath, thin; dry woods, fields and waste grounds; biennial ..... *Lobelia inflata*
99. Leaves pubescent on both sides with short, stiff hairs, especially near the base and margins, thickish and firm; dry, mostly sandy soil; perennial ..... *Lobelia spicata*
100. Margins remotely denticulate, none of the leaves lobed or pinnatifid; leaves usually much less than 10 cm. long, 1–3 cm. broad, obovate to oblanceolate, if pubescent, with erect hairs about 1 cm. long 101
100. At least some of the leaves lobed or pinnatifid, or if not, then not otherwise as above 101

101. Leaves glabrous, or nearly so, more or less purple-veined ..... *Hieracium venosum*
101. Leaves, at least the younger ones, villous-hirsute, not purple-veined ... *Hieracium gronovii*
H. paniculatum
102. Leaves prickly on the margins and veins beneath ..... *Lactuca scariola*
102. Leaves not prickly as above 103

103. Petioles and leaf rachises not hollow ..... *Lactuca* spp.
103. Petioles and leaf rachises hollow ..... *Taraxacum officinale*
104. Leaves prickly, large 105
104. Leaves not prickly 106
105. Leaves glabrous; blades very rugose, with whitish, stout, blunt spines on the veins, especially the midvein beneath, and scattered on the upper surface, crenate, dark green ..... *Dipsacus sylvestris*
105. Leaves more or less strigose-pubescent or hispid above and below; margins and sometimes the veins beneath with sharp spines, usually more or less triangular-lanceolate lobed or pinnatifid, or sometimes merely serrate, dark or bright green ..... *Cirsium* spp.
106. Most of the leaves with pinnatifid, lobed, or incised blades 107
106. Most of the leaves not with pinnatifid, lobed or incised blades 133
107. Most of the blades pinnately lobed, incised, or pinnatifid (excluding all that are only 2- or 3-lobed) 108
107. Most of the blades palmately lobed (including all that are 2- or 3-lobed) or incised 125
108. Blades suborbicular or broadly ovate in outline, broadest across the lowest pair of segments or lobes, the segments or lobes shallow or deep, coarsely toothed or incised, petioles expanded at the base and clasping, the blades with or without large irregular patches of pale green or white on the upper surface, 3–7 lobed or divided 109
108. Blades not suborbicular or broadly ovate in outline, not broadest at base, nor splotched with pale green or white 111
109. Blades 3–7-divided, the terminal segment 3-lobed, glabrous or nearly so throughout, not splotched with pale green or white ..... *Rudbeckia laciniata*
109. Blades 5–7-lobed, the lobes shallow or deep, more or less rough-pubescent throughout, usually splotched with pale green or white 110
110. Perennial, with large scaly rhizomes usually at or near the surface of the ground ..... *Hydrophyllum canadense*
110. Biennial, without scaly rhizomes ..... *Hydrophyllum appendiculatum*
111. Roots, petioles, and veins with bright orange or yellow sap; segments mostly 7, obovate or ovate, 2–3.5 cm. long, 1–2.5 cm. broad, crenate-lobed, the lobes or teeth all very obtuse, petioles dilated at the base and clasping ..... *Chelidonium majus*
111. Plants not with bright orange or yellow sap, or if so, not otherwise as above 112
112. Leaves with stellate-pubescence; more or less lobed or pinnatifid, 3–15 cm. long, the lobes acute and toothed ..... *Capsella bursa-pastoris*
112. Leaves not with stellate pubescence 113
113. Leaves granular-viscid on the lower side; spatulate-oblong in outline, pinnatifid or lyrately lobed, 4–10 cm. long, about 1 cm. broad, hoary-pubescent with white scale-like hairs, often in pairs ..... *Lepidium campestre*
113. Leaves not granular-viscid on the lower side, or not otherwise as above 114
114. Blades runcinate-pinnatifid 115
114. Blades not runcinate-pinnatifid 116
115. Leaves pubescent with rather long, scattered, stiff hairs; lobes 3–6 pairs and the terminal, dentate, crenate, lobed or entire ..... *Sisymbrium officinale*
115. Leaves glabrous, or if pubescent, with soft, downy hairs; lobes wavy-toothed or entire, often auriculate at the base, usually 6 or more pairs and the terminal one ..... *Sisymbrium altissimum*
116. Blades deeply pinnatifid, *i.e.*, divided to, or almost to the midvein, the midvein unmargined or slightly margined, the lateral segments distinct or almost distinct and rather uniform in size 117
116. Blades not deeply pinnatifid as above 123
117. Plants strictly aquatic, usually in small streams or at outlets of springs, many plants occurring together and covering the water surface; leaves not in rosettes (except in late winter), 3–9 segments, terminal one larger than the lateral and nearly orbicular, about 1 cm. broad ..... *Nasturtium officinale*

117. Plants terrestrial, or if in aquatic habitat, the leaves in distinct, usually symmetrical rosettes 118
118. Terminal lobe orbicular or suborbicular, 2–5 cm. broad, the lateral segments distinct, or nearly so, all entire or undulate 119
118. Terminal lobe not orbicular, or if so, not otherwise as above 120
119. 1–4 pairs of lateral segments ..... *Barbarea vulgaris*
119. 4–8 pairs of lateral segments ..... *Barbarea verna*
120. Terminal lobe greatly exceeding the lateral ones in size 121
120. Terminal lobe not greatly exceeding the lateral ones in size although it may be distinctly larger, narrowed at the base, 2–8 pairs of lateral segments; sometimes submerged ..... *Cardamine pensylvanica*
121. Leaves pubescent with scattered stiff hairs; 2–4 lateral segments ..... *Brassica nigra*
121. Leaves glabrous or puberulent 122
122. Blades spatulate in outline, numerous very small lateral segments, glabrous or puberulent; common weed of fields, gardens, and waste grounds ..... *Lepidium virginicum*
122. Blades oblong or oblanceolate in outline, 6–8 small lateral segments, smooth and glabrous; bases of petioles dilated and clasping; chiefly in moist or wet places, or shallow water ..... *Rorippa islandica*
123. Blades hirsute or pubescent, dotted with minute glands; obovate or broadly oblong in outline, lyrate-pinnatifid, the lobes usually shallow or deeper toward the base, undulate-dentate ..... *Salvia lyrata*
123. Blades glabrous or nearly so 124
124. Petioles usually as long as or longer than the blades; blades spatulate or oblanceolate in outline, rarely over 2 cm. broad, irregularly pinnatifid or subpinnatifid and the lobes very irregularly dentate, not rugose, the margins more or less strongly but loosely crisped ..... *Chrysanthemum leucanthemum*
124. Blades sessile or very short-petioled; oblong to lanceolate in outline, usually more than 2 cm. broad, more or less deeply lobed or pinnatifid, the lobes with sinuate-crenate to dentate margins, conspicuously rugose above ..... *Verbascum blattaria*
125. Stipules in the form of ochreae; blade hastate, the basal lobes spreading; blades 2–7 cm. long, glabrous and entire, or the basal lobes 1–2-toothed ..... *Rumex acetosella*
125. Stipules, if present, not in the form of ochreae 126
126. Blades shallowly 3–9-lobed, small stipules adnate to the bases of the petioles, the tips free 127
126. Blades more or less deeply 3- or 5-lobed, without stipules or with large membranous stipules, the tips not free 129
127. Petioles glabrous or puberulent, blades 7–9-lobed, the lobes rounded at the apex ..... *Heuchera americana*
127. Petioles retrorsely hirsute, blades 3–5-lobed, the lobes acute or acuminate at the apex 128
128. Stipules with deeply fimbriate tips ..... *Tiarella cordifolia*
128. Stipules merely glandular-ciliate or slightly and shallowly fimbriate ..... *Mitella diphylla*
129. Lobes with entire margins; blades reniform or broadly ovate in outline; usually broader than long, thickish and firm, 4–12 cm. broad, 3-lobed, the lobes ovate 130
129. Lobes serrate, dentate, crenate, or incised 131
130. Lobes acute at the apex ..... *Hepatica acutiloba*
130. Lobes obtuse or rounded at the apex ..... *Hepatica americana*
131. Blades and petioles smooth and glabrous, or nearly so, blades 3–5-lobed, the lobes obtusely cut and toothed; swamps, ponds, and wet ditches ..... *Ranunculus sceleratus*
131. Blades and petioles more or less pubescent, or if glabrous, then not otherwise as above 132
132. Blades broadly reniform, broader than long, 3-lobed, the lobes usually acute and toothed, densely hirsute throughout, or rarely glabrate; woodland species ..... *Ranunculus recurvatus*

132. Blades palmately 3–5-lobed, orbicular or broadly ovate in outline, the lobes acute or acuminate at the apex, coarsely and sharply dentate and incised, very veiny, more or less finely rough-pubescent; roadsides, fields, and waste grounds ..... *Leonurus cardiaca*

133. At least some of the blades distinctly cordate at the base 134

133. None of the blades distinctly cordate at the base 150

134. Leaves with membraneous, sheathing, united stipules (ochreae) 135

134. Leaves without stipules, or if present, not in the form of ochreae 136

135. Margins crisped, blades dark green, more or less papillose ..... *Rumex crispus*

135. Margins not crisped, merely undulate, blades bright green, petioles and veins usually red or reddish ..... *Rumex obtusifolius*

136. Blades with entire, undulate or angled margins 137

136. Blades serrate, dentate, crenate, or crenulate 139

137. Plants aquatic; blades yellow-green, deeply cordate, with a conspicuous crimson spot at the base of the midvein ..... *Nuphar advena*

137. Plants terrestrial 138

138. Blades angled, the angles obtuse or acutish; blades orbicular or broadly oblong, 1–2.5 cm long, dark green, firm and leathery, glabrous throughout ..... *Cardamine bulbosa*
C. douglassii

138. Blades entire or undulate; ovate or oval, 2–5 cm. long, prominently pinnately-veined, obtuse and rounded at the apex or acute, smooth and glabrous except for the long-ciliate petioles and ciliate margins, especially on the younger leaves ..... *Lysimachia ciliata*

139. Blades deltoid-ovate or oblong in outline with flaring teeth at the base, sparingly and shallowly serrate above, 3–5 cm. long, obtuse or acute at the apex ..... *Viola sagittata*

139. Blades not as above 140

140. Most of the leaves obtuse to very obtuse and rounded at the apex 141

140. Most of the leaves acute or sometimes acuminate at the apex 144

141. Blades rugose, especially above, dark green above, lighter beneath and often purplish; serrate-crenate, ovate or orbicular ..... *Senecio aureus*

141. Blades not rugose above, bright green 142

142. Sinuses at the base of the blade wide and shallow; crenate, sometimes 2–3-lobed ..... *Ranunculus abortivus*

142. Sinuses not broad, sometimes wanting 143

143. Blades crenate or crenate-dentate, some of them sometimes 3-divided ..... *Thaspium trifoliatum*

143. Blades sharply serrate, some of them sometimes ternately decompound ..... *Zizia aurea*

144. Blades mostly less than 2.5 cm. long, broadly ovate to orbicular, regularly and often rather finely crenate-serrate 145

144. Blades mostly 3–7 cm. long, broadly ovate to almost lanceolate, coarsely and frequently irregularly serrate or dentate 147

145. Teeth conspicuously yellowish callose-tipped; sparingly pubescent with short, flat, ribbon-like hairs ..... *Campanula americana*

145. Teeth not yellowish callose-tipped 146

146. Leaf tufts arising directly from the rhizome ..... *Viola papilionacea*
V. triloba
V. blanda

146. Leaf tufts arising from the ends of short or dwarfed stems, several stems from each rhizome, blades rarely over 2 cm. broad, with small stipules ..... *Viola striata*
V. rostrata
V. conspersa

147. Leaves densely velvety-pubescent above and below; blades ovate to broadly ovate, irregularly shallowly dentate-crenate or crenulate ..... *Aster undulatus*

147. Leaves not densely pubescent as above 148

148. Blades large, 10–15 cm. long, 5–13 cm. broad, with broad, sharp-pointed teeth, sinuses deep and irregular, rough-pubescent above with scattered hairs; frequently in colonies ..... *Aster macrophyllus*
148. Blades 3–8 cm. long 149

149. Blades sharply dentate, the teeth with conspicuous incurved, bristle-like tips 0.5–1 mm. long; chiefly in the Plateau ..... *Aster divaricatus*
149. Blades serrate, or sometimes the teeth blunt, sometimes with bristle like tips but always minute (tips less than 0.5 mm. long), usually purple beneath, petioles ciliate at least toward the base; common in woods throughout the State ..... *Aster cordifolius*
150. Leaves densely woolly with long, branched hairs above and below, or white-tomentose, especially below; not 3-veined 151
150. Leaves not densely woolly or white-tomentose as above, or if white-tomentose below, then 3-veined 152

151. Leaves woolly with long, coarse, branched and interlacing hairs, mostly 5–15 cm. long ..... *Verbascum thapsus*
151. Leaves softly white-tomentose, especially densely so below, 2–5 cm. long ..... *Gnaphalium* spp.
152. Leaves with stellate or 2-branched hairs, although some of the hairs may be simple 153
152. Pubescence when present of simple hairs 155

153. Leaves mostly 2–4 cm. long 154
153. Leaves mostly 0.5–1.5 cm. long; entire or dentate near the apex, more or less pubescent on the upper surface with simple, 2-branched and stellate hairs; chiefly in the southern counties ..... *Draba verna*
154. Pubescence of stellate and 2-branched hairs, not appressed, blades narrowed into slender petioles about the same length as the blades, entire or sparingly shallow-toothed; old sandy fields and pastures ..... *Arabidopsis thaliana*
154. Pubescence of 2-branched and simple, appressed hairs, blades narrowed into short petioles, coarsely toothed or repand-denticulate; cultivated and waste grounds ..... *Erysimum repandum*

155. Blades prominently 3- or 5-veined 156
155. Blades not prominently 3- or 5-veined 165
156. Leaves linear, grass-like, 3–15 cm. long, 2–6 mm. broad, acuminate at the apex, 3-veined ..... *Plantago aristata*
156. Leaves not linear, or if so, not many times longer than broad 157

157. Leaves dull dark green and arachnoid above, densely white-tomentose beneath, 3-veined, obovate, spatulate or broadly oval, often forming broad patches ..... *Antennaria plantaginifolia*
157. Leaves not white-tomentose beneath 158
158. Blades entire or sometimes repand-denticulate 159
158. Blades sharply serrate or dentate, the teeth usually shallow 162

159. Leaves villous-pubescent 160
159. Leaves glabrous or short-pubescent 161
160. Leaves densely villous-pubescent, oblong, obovate or sometimes linear, acute or obtusish at the apex, entire; prairie species rare except locally ..... *Castilleja coccinea*
160. Leaves villous-pubescent, but not densely so, grayish-green, obovate or spatulate, obtuse or acutish at the apex, entire or repand-denticulate; moist pioneer sites and open swamp forests of the southern and southeastern Plateau ..... *Plantago virginica*

161. Leaves glabrous, not over 2.5 cm. long, broadly ovate to orbicular, sessile or nearly so, pale green, in a 4–8-leaved rosette, the leaves paired with regard to size ..... *Sabatia angularis*

161. Leaves short-pubescent with a tuft of brownish or whitish hairs at the base of the margined petioles, 4–15 cm. long, narrowly oblong-lanceolate or linear- elliptic, dark green ..... *Plantago lanceolata*

162. Blades sharply serrate, the teeth rather shallow and not remote, tapering gradually into short, margined petioles, smooth and glabrous except for the rough-ciliolate margins and the ciliate petioles, internodes slightly elongated.. ..... *Solidago gigantea*

162. Blades serrate or dentate, but sparingly so, more or less abruptly narrowed into margined petioles, mostly bristly-hispid, leaves distinctly tufted and usually spreading on the ground 163

163. Leaves thin, bright green, rather softly pubescent above and below, usually some of them 3-lobed or 3-divided ..... *Rudbeckia triloba*

163. Leaves thick, more or less hirsute or hispid, never 3-lobed or 3-divided 164

164. Leaves dark green, blades of at least some of them abruptly narrowed into distinctly margined petioles, the margins 0.8–3 mm. broad; confined to the prairies ..... *Rudbeckia speciosa*

164. Leaves bright green, blades narrowed into very slightly margined petioles; prairie species, but also in fields, along roadsides, and in waste grounds..... ..... *Rudbeckia hirta*

165. Blades entire, undulate, denticulate, crenulate or serrulate (*i.e.*, entire or obscurely toothed) 166

165. Blades distinctly serrate, dentate, or crenate 186

166. Petioles with stipules in the form of ochreae; leaves large, glabrous 167

166. Stipules, if present, not in the form of ochreae 168

167. Margins crisped, blades dark green; more or less papillose ..... *Rumex crispus*

167. Margins not crisped, merely undulate; petioles and veins usually red or reddish, blades bright green ..... *Rumex obtusifolius*

168. Blades granular-viscid on the lower side, hoary-pubescent with scale-like hairs, often in pairs, entire, obtuse at the apex, blades tapering to petioles..... ..... *Lepidium campestre*

168. Blades not granular-viscid on the lower side 169

169. Blades conspicuously glandular-dotted; ovate, 1–5 cm. long, crenate with shallow teeth, undulate or entire, obtuse or acutish at the apex, abruptly narrowed at the base and usually subcordate, sparingly pubescent throughout; common in waste grounds and disturbed forests ..... *Prunella vulgaris*

169. Blades not glandular-dotted 170

170. Blades entire 176

170. Blades undulate, denticulate, serrulate or crenulate, sometimes minutely so... 171

171. Blades crenulate or plicate-crenulate; oval, elliptic or orbicular, reticulately veined, smooth and glabrous, petioles unmargined; Hemlock-Hardwood forests 172

171. Blades not crenulate or plicate-crenulate, petioles margined when present 173

172. Blades plicate-crenulate, broadly oval or elliptic, thin, membranous, dull dark green, usually mucronulate at the apex, longer than the petioles..... ..... *Pyrola elliptica*

172. Blades crenulate, orbicular or oval, coriaceous, bright green and shining above, usually as short as the petioles ..... *Pyrola rotundifolia*

173. Leaves smooth and glabrous, margins closely, irregularly, and sharply serrulate and curled under, blades usually strongly but loosely rugose, oblong, 2–7 cm. long, 0.5–2 cm. broad, bright green; wet pioneer habitats ..... *Epilobium coloratum*

173. Leaves not glabrous, or if so, not otherwise as above 174

174. Petioles mostly much shorter than the blades 175

174. Petioles mostly as long as or longer than the blades, slender and slightly margined, leaves 8–30 cm. long, 2–4.5 cm. broad, blades ovate-lanceolate or oblong, serrulate or rarely entire, more or less scabrous above with short hairs; uncommon except locally in prairie areas ..... *Solidago rigida*

175. Blades irregularly undulate-denticulate, the narrowed portion at the base frequently dentate, acute or acuminate at the apex, pinnately-veined, the midvein broad and the lateral prominent, lanceolate or oblong-lanceolate; common in old fields, along roadsides and streams, and in waste grounds ..... *Oenothera biennis*
Gaura biennis

175. Blades regularly and minutely denticulate, obtuse or acutish at the apex, 1-veined, oval, ovate, obovate, or oblanceolate, thick and leathery; uncommon except locally in wet or moist grounds ..... *Saxifraga pensylvanica*

176. Largest leaves mostly less than 1 cm. broad; linear, oblong, oblanceolate, or if less than 5 cm. long, sometimes spatulate 177

176. Largest leaves mostly more than 1 cm. broad; oblanceolate, obovate or spatulate 182

177. Leaves densely silky-pubescent with long spreading hairs, narrowly oblanceolate; weed, especially of grainfields ..... *Agrostemma githago*

177. Leaves not densely silky-pubescent as above 178

178. Leaves hoary-pubescent; roots reddish 179

178. Leaves not hoary-pubescent 180

179. Leaves obscurely veined, bright green ..... *Lithospermum arvense*

179. Leaves distinctly 1-veined, pale green ..... *Lappula echinata*

180. Leaves linear or narrowly linear-oblanceolate, 2–8 cm. long, 3–6mm. broad, dark green, rather thick and succulent, rigid, margins ciliate, otherwise glabrous or glabrate; chiefly in the Plateau, especially in upland *Andropogon* communities and in clearings ..... *Dianthus armeria*

180. Leaves spatulate, oblanceolate or oblong, usually less than 5 cm. long 181

181. Plants stoloniferous, leaves tufted and ascending, oblong or oblanceolate, 2–5 cm. long, blades narrowed into broadly margined petioles, appressed short-pubescent; shallow pools, sluggish streams or other wet grounds ..... *Myosotis scorpioides*

181. Plants not stoloniferous, leaves in a flat rosette, oblanceolate or spatulate, 1–2 cm. long, blades narrowed into slender margined petioles, puberulent or glabrate, mucronate, margins more or less ciliate; old fields and open woods, especially in sandy soils ..... *Silene antirrhina*

182. Plants of rocky ledges, crevices, and cliff bases, Hocking, Jackson, Pike, and Ross Counties; leaves obovate or broadly spatulate, mostly 2–4 cm. long, obtuse at the apex but pointed, margins more or less crisped ... *Silene rotundifolia*

182. Plants not as above 183

183. Leaves tufted, ascending, thin and tender, smooth and glabrous except for occasional hairs on the margins, upper surface and the midvein beneath, spatulate to obovate, obtuse and rounded at the apex, mucronate, 5–10 cm. long, 1–2 cm. broad, petioles margined, much longer than the blades; common in moist pioneer habitats ..... *Valerianella intermedia*

183. Leaves spreading on the ground, or if ascending, not otherwise as above 184

184. Petioles as long as or longer than the blades, margined, slender, leaves glabrate, thick and firm, dark green; 2–25 cm. long, spatulate or oblanceolate, 1-veined; Oak-Chestnut woods or forest borders ..... *Silene virginica*

184. Petioles much shorter than the blades, broadly margined, bright green, not thick and firm, softly pubescent throughout; pioneer habitats 185

185. Blades pinnately veined, the veins prominent and commonly lighter green or yellowish ..... *Lychnis alba*

185. Blades 1-veined, the lateral veins not prominent ..... *Silene noctiflora*

186. Blades deltoid-ovate or oblong in outline with flaring teeth or incised-dentate at the base, sparingly and shallowly serrate above, petioles unmargined, slender ..... *Viola sagittata*

186. Blades not as above 187

187. Margins strongly and closely crisped, rest of blade flat or nearly so; obovate to oblanceolate 188

187. Margins not strongly and closely crisped, or if so, rest of blades more or less rugose, or not otherwise as in 188 189
188. Blades thick, firm and somewhat succulent, light green and obscurely veined above, reddish beneath and 1-veined, short-pubescent or glabrate, mostly dentate, the abruptly narrowed basal portion entire, petioles broad, margined; dry or rock banks along forest borders, in the Plateau .... *Saxifraga virginiensis*
188. Blades thickish, dark green, 1-veined above, sparingly long-pubescent above, smooth and glabrous beneath, sharply serrate-dentate or almost laciniate; wooded slopes of ravines or stream banks ..... *Arabis laevigata*
189. Leaves more or less hispid-pubescent, the hairs not minute, mostly easily seen with the unaided eye 190
189. Leaves glabrous, or with minute hairs on the upper surface, or the margins sometimes ciliate 194
190. Blades mostly abruptly narrowed into slender, slightly margined petioles usually longer than the blades 191
190. Blades mostly cuneate at the base or gradually narrowed into relatively broad, margined petioles shorter than the blades 192
191. Blades coarsely and usually deeply dentate, sometimes incised-dentate toward the base, pubescence spreading, 2.5–7 cm. broad ..... *Erigeron annuus*
191. Blades sparingly shallow-serrate or almost entire, pubescence somewhat appressed, 0.5–1.5 cm. broad ..... *Erigeron strigosus*
192. Petioles long-ciliate; leaves 2–10 cm. long, 1–2 cm. broad, sparingly coarsely dentate or incised-dentate, biennial; weed of fields, roadsides and waste ground ..... *Erigeron canadensis*
192. Petioles not long-ciliate, perennials; mostly forest or woodland border species .. 193
193. Blades thin, rather sparingly pubescent above and below, the hairs not long, coarsely or shallowly dentate; swamp forests or moist pioneer habitats ..... *Erigeron philadelphicus*
193. Blades thickish and firm, long-pubescent above and below, the hairs stiff or stiffish, especially dense along the margins, sparingly and remotely shallow-toothed; woodland borders, rarely in pioneer habitats ..... *Erigeron pulchellus*
194. Leaves with a garlicky odor when crushed; oblanceolate, coarsely dentate, long-petioled, in a flat rosette, biennial; waste grounds ..... *Thlaspi arvense*
194. Leaves not with a garlicky odor when crushed, perennials 195
195. Most of the blades sharply serrate all around, or the narrowed basal portion entire, the teeth not shallow, appressed or remote, blades very thin and flat, or curled as though not fully expanded, bright green, abruptly narrowed into slightly margined petioles, glabrate above, glabrous below, not scabrous; forest species, especially in Beech-Sugar Maple and Oak-Chestnut types 196
195. Blades not mostly sharply serrate all around, thin, or abruptly narrowed into slightly margined petioles as above 197
196. Leaves 1.5–5 cm. long, 1–2 cm. broad, usually curled as though not fully expanded, blades ovate to lanceolate ..... *Solidago caesia*
196. Leaves 5–15 cm. long, 2–5 cm. broad, flat, blades ovate to broadly elliptic, often doubly serrate ..... *Solidago flexicaulis*
197. At least the upper surface of the blades more or less scabrous (when rubbed toward the base) with minute, stiffish hairs, or minutely pubescent with more than occasional hairs and not scabrous 198
197. Leaves entirely glabrous, or glabrous except for the ciliate or ciliolate (sometimes very minutely so) margins 202
198. Leaves large, mostly 8–20 cm. long 199
198. Leaves all usually much less than 8 cm. long 200
199. Blades oval or elliptic, thickish and somewhat rugose, very rough above when rubbed toward the base, obtuse or acute at the apex; swamps, bogs, and seepage slopes ..... *Solidago patula*

199. Blades lanceolate or elliptic-lanceolate, rather thin and not rugose, acute or subacuminate at the apex, pubescent above with minute hairs but not scabrous; dry pioneer habitats ..... *Solidago juncea*

200. Blades rugose above and below, petioles usually shorter than the blades; minutely pubescent or scabrous above, ciliolate, blades oval, ovate or lanceolate, thickish, sharply serrate ..... *Solidago rugosa*

200. Blades not rugose, petioles usually longer than the blades 201

201. Plants of dry pioneer habitats, especially in sandy or clayey soil; densely minutely pubescent or scabrous, blades mostly spatulate ..... *Solidago nemoralis*

201. Plants of swamp forests, stream banks and roadside ditches; pubescent, scabrous or glabrate, blades ovate or ovate-lanceolate ..... *Aster prenanthoides*

202. Leaves thick and succulent, very smooth and flat, glaucous or light green, glabrous except for the ciliolate margins (sometimes minutely so), shallowly crenate or serrate 203

202. Leaves bright or dark green, usually thickish and sometimes slightly succulent, but usually not extremely smooth, never glaucous, with or without marginal hairs 204

203. Leaves not glaucous, light green; Oak-Chestnut woods of the Plateau; margins conspicuously ciliolate, mostly crenate, blades obtuse to very obtuse and rounded at the apex, petioles shorter than the blades, broad and flat ..... *Solidago erecta*

203. Leaves usually conspicuously glaucous as well as light green; cliffs and wooded bluffs, or dry roadside banks, general distribution; margins with minute, rigid, forward-pointing hairs, irregularly serrate-crenate, petioles slightly to broadly margined, shorter or longer than the blades, blades acute or obtuse and rounded at the apex .... *Aster laevis*

204. Blades obovate with a cuneate base, suborbicular or broadly spatulate, more or less rugose, dark green, very obtuse and rounded at the apex, regularly crenate-dentate, often purple below, entirely glabrous or the very young ones silvery webbed-hairy, in a flat rosette ..... *Senecio obovatus*

204. Blades not as above 205

205. Blades ovate, abruptly narrowed into slightly margined petioles usually longer than the blades; swamp forests ..... *Aster lateriflorus*
A. prenanthoides

205. Blades not both ovate and abruptly narrowed into slightly margined petioles 206

206. Blades sharply serrate with flaring, acuminate teeth, chiefly from the middle to the apex, acute or acuminate at the apex, long-tapering at the base, minutely ciliolate; swamp forests ..... *Aster tradescanti*

206. Blades not sharply serrate as above, shallow-serrate, denticulate or almost entire 207

207. Leaves ciliate; spatulate or oblanceolate, 2–10 cm. long, 0.5–1.5 cm. broad, sparingly shallow-serrate above the middle or almost entire; dry or moist pioneer sites ..... *Aster pilosus*

207. Leaves not ciliate; blades lanceolate or oblong-lanceolate, irregularly denticulate, 4–10 cm. long, 1–1.5 cm. broad; wet pioneer sites ..... *Aster puniceus*

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C. E. Taft.

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